NSK

Chapter 1
What Is A Linear Guide?

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NSK Ltd.

**Precision Machinery & Parts
e-Project Team**

Lesson 1: Construction of Linear Guides

We are going to learn about the position of NSK linear guides as one of the linear motion bearings and their construction.

Section 1 | Types of Linear Motion Bearings

Linear motion bearings have a mechanism to bear loads and to guide their linear movement simultaneously, and are classified into the following four major groups.

Sliding contact linear motion bearings

This type is the oldest, simplest, least expensive way, and it still has wide range of applications. In general all sliding contact bearings have greater friction coefficient than other types described hereunder, and because of this, they are considered to be inferior to these guides for precise positioning applications. With lubricant forcibly maintained between two relatively moving objects, a relative speed helps to pull in lubricant, and thereby, a thin film is formed.

Rolling element linear motion bearings

This type decreases friction utilizing rolling contact via rolling elements (balls, rollers, etc.) that are placed between two relatively moving objects. There are many specialized manufacturers and each manufacturer provides wide variety of products. Because of its superiority over the sliding contact linear motion bearings as described hereunder and because of its availability, this type has won the position as an essential component for the equipment that requires highly accurate positioning operation.

Hydrostatic or aerostatic linear motion bearings

When extremely accurate and quiet operation must be attained, a guide without mechanical contact between its elements is often chosen. With pressurized fluid forcibly supplied between two relatively moving objects, one of them is kept floating by the fluid. Depending upon the fluid in use, it is classified in aerostatic and hydrostatic linear motion bearings. Although this type of guides is very advantageous for particular purposes, it is usually costly, difficult in manufacturing, and requires expensive auxiliary apparatus. Yet, this type is sometimes used for ultra-precision machines.

Magnetic linear motion bearings

By means of magnetic force, either repelling or attracting, one of the two relatively moving objects is kept afloat. Use of electromagnet makes it costly and ineffective in energy consumption. This type has very limited applications.

Although numerous sliding contact linear motion bearings have long been used, their positions are being quickly replaced by the rolling element linear motion bearings. This is because the sliding contact bearings have the following disadvantages for today's needs for high speed, high precision, high quality and long term maintenance-free operation.

◊ High friction, and a large difference between their static and dynamic friction.

◊ It is hard to control positioning operation because variation of external loads and speeds largely affect the friction force.

◊ Poor positioning accuracy, particularly repeatability.

◊ It is not suitable for extremely low speed or high-speed applications. Difficult to predict their life span.

◊ It is hard to predict their rigidity. Hence, it is difficult to achieve an optimum design for them.

◊ Frequent and periodical maintenance is required for them to maintain accuracy.

◊ Their quality largely depends on workmanship of scalping and clearance adjustment, etc
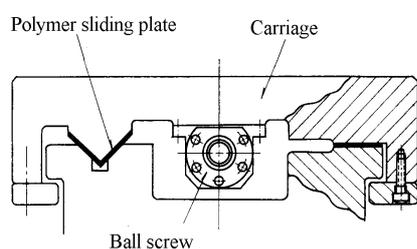
Sliding contact linear motion bearing
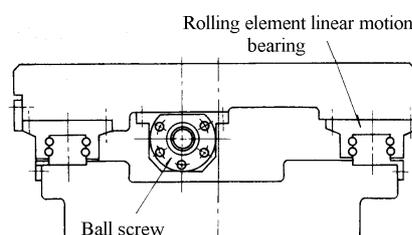
Rolling element linear motion bearing

Section 2 — Types of Rolling Element Linear Motion Bearings and Position of Linear Guides

The rolling element linear motion bearings are classified as shown below.

Family-tree of rolling element linear motion bearing
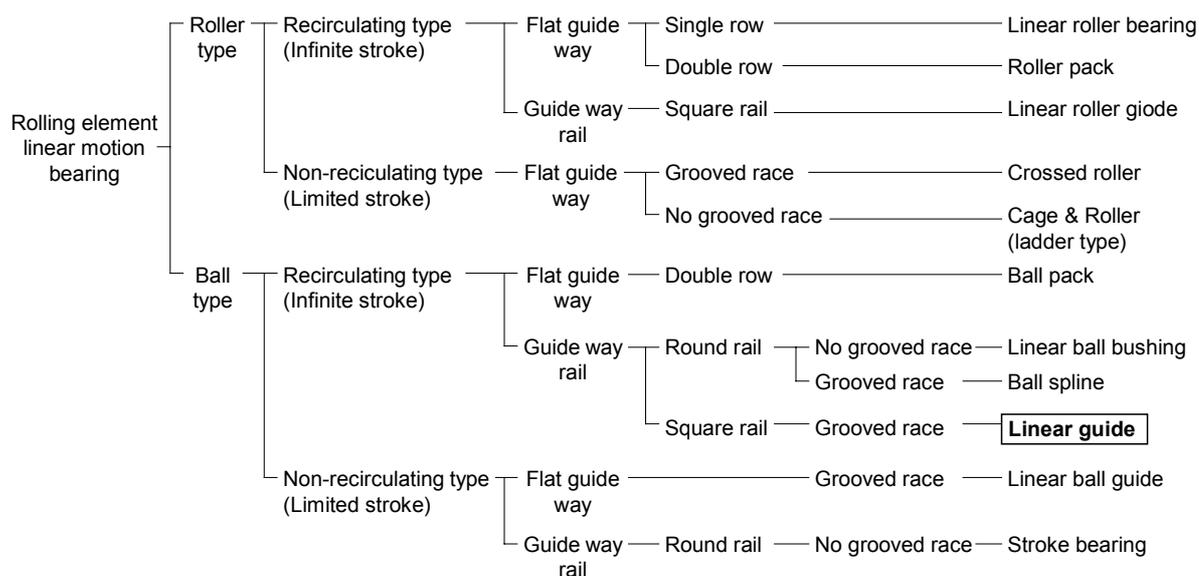
The above family tree indicates that the linear guides are positioned as "a unit component capable to guide a ball slide to make its stroke infinite by recirculating balls."

✍ *Notes* : **What is friction force?**

When you want to slide a box sitting on a floor, it does not move while your pushing force is yet too small (static frictional force). But, it starts moving when your force has reached a certain level. In order to keep the box moving on, you need to maintain your pushing force at its dynamic frictional force, which is far less than the static friction force.

As described above, the **friction force** is the force that two objects exert upon each other through their contact surface and hinder each other's relative movement when they are in contact.

The intensity of frictional force varies with the state of contact. A friction force of rolling contact is usually smaller than that of sliding contact.

Sliding friction ↔ Sliding guide
(Requires larger force)

Rolling friction ↔ Rolling element guide
(Requires far less force)
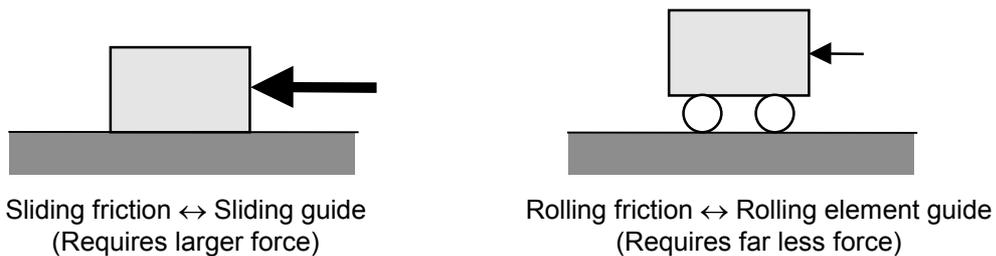
Section 3 | Structure of Linear Guides
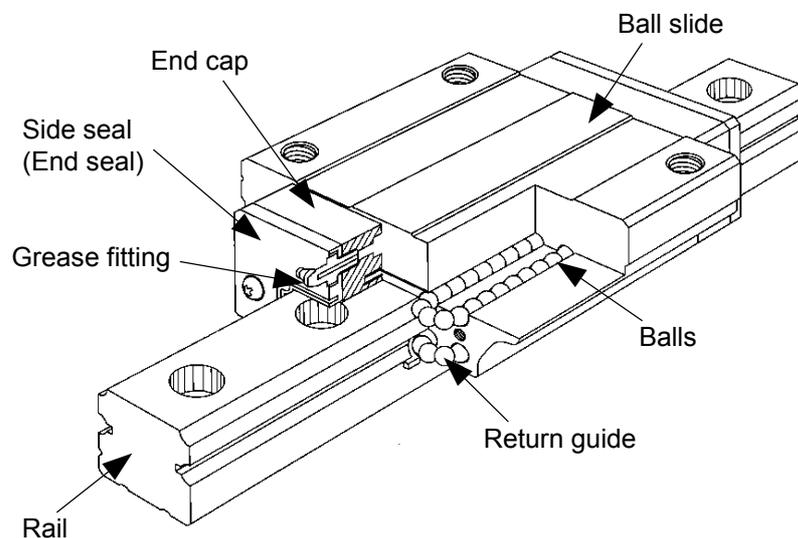
The linear guides consist of a mechanism in which steel balls are circulated infinitely to enable an infinite stroke of ball slides theoretically. Balls roll along the ball groove formed on a rail and a ball slide and there, they are scooped at the point A by the tip of an end cap. There, they are forced to change their circulating direction by a return guide of the end cap and guided to a circularting hole provided inside of the ball slide. The balls continue to pass through the hole to the other end of the ball slide and, further, go through the circulation circuit to the tip of the end cap of the other side and then, return to the ball grooves of rail and ball slide. Thus, the balls repeat their endless circulation motion.

⌛ *Coffee Break* ⌛   History of the Linear Guides

Attempts to replace sliding with rolling contact appear to have been entertained even in the prehistoric age. Figure 1 shows a wall painting in Egypt. A huge stone is being transported rather easily on rolling logs laid underneath it. The way those used logs are being carried over to the front side depicts exactly how a rolling element circulation mechanism functions in today's rolling element linear motion bearings.
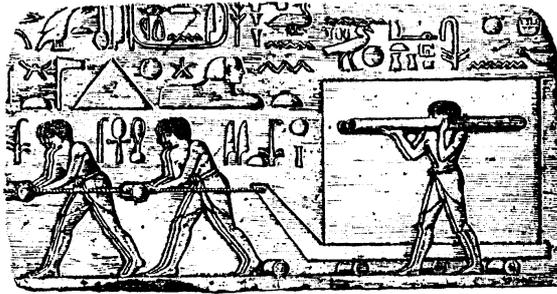
Figure 1 : Wall printing in Egypt

Although rolling element linear motion bearings find their origin way back in the ancient times, they did not easily come to common use as mechanical elements until the early 20th century, when those rolling element linear motion bearings using steel balls for their accurate and smooth linear movement (a non-recirculation type) facilitated an application to precision machines.
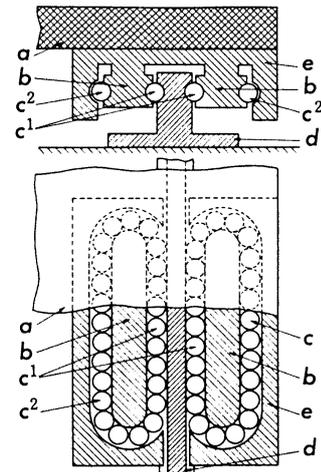
Figure 2 : French patent

The basic mechanism of rolling element linear motion bearings was established in 1946 when a U.S. company, Thomson, commercialized ball bushings (a ball re-circulation type).

The basis of today's linear guides (rolling units with rails) can be seen in a patent granted in France in 1932 (see Fig. 2). This patent, though encompassing all of the fundamental functions of linear guides, still had to keep waiting for decades before their application debut in the market. During that time, several machinery parts that use rolling elements such as ball screws or ball splines were commercialized. Various types of ball bushings (linear ball bearings) were also brought in to the market, including an open type bearings.
In the meantime, numerous inventions and improvements of similar kinds were made to the linear guides.

In 1973, THK introduced railed rolling element linear motion units (LM guide, NSR type), a modification from ball splines, for use in general industrial machines. We, NSK started our own full-scale research and tests, applying patents in 1979. We patented the LK type (marketed in earlier years, but the production of this model was terminated later) and the LY type in 1981 as well, and brought them into the market in 1983 after we had fully examined their properties and characteristics, and even actually tested them on some particular users machines. Thus, we have added many more series of products to this day.

Lesson 2: Merits, Applications and Combination of Linear Guides

Since the linear guides are one of the rolling element linear motion guides, they have various merits superior to the sliding contact linear motion guides.

| **Section 1** | **Features of Linear Guides** |

• Difference between static friction force (force to initiate its motion) and dynamic friction force is small. • Variation of friction force due to speed is small. • Consequently, less stick-slip.	➔	Precise positioning can be made since linear guides can be fed in minute steps and/or in a high speed in a stable manner.
• Low friction force.	➔	High speed, energy saving and low heat generation.
• Minimal in loosing precision by wear. (Wear is far less than the sliding contact guide way.)	➔	Capable to maintain accuracy for a prolonged time.
• Possible to predict life expectancy.	➔	Possible to have optimum design for required life.
• Easy to design the part of a linear motion bearing (Guide way bearing). • Linear motion bearing unit with guaranteed quality.	➔	Cuts assembly cost. Ensures stable quality.
• Easy maintenance.	➔	Low running cost.

✎ *Notes* : **What is stick-slip?**

Just imagine that you want to push something heavy. That object will not move with any weak force you apply. Once the force has reached a certain level, it will start moving all of a sudden. Once it has started moving, pushing (puling) force is less than that of starting. This phenomenon derives from the fact that its friction coefficient during motion is much lower than that of static friction, and also from the fact that motion does not start until the force exceeds its static friction force. The same is applicable to a feed mechanism, when there is a large difference between static and dynamic friction coefficient.

It remains caught up (stick), or it starts sliding (slip), which results in a step rise in acceleration. This phenomenon is called "stick-slip." Due to this, you cannot get a uniform feed speed and will lose the precision in positioning.

Any bearing that relies on sliding or rolling mechanical contact between components has stick-slip to some degree. The sliding contact linear motion bearing has significant difference in static and dynamic friction, while that of the rolling elements linear motion bearing is usually low enough to ignore.

Section 2 │ Application Examples of Linear guides

1 Superior friction characteristic

[Example 1] Precision positioning table

Single axis table
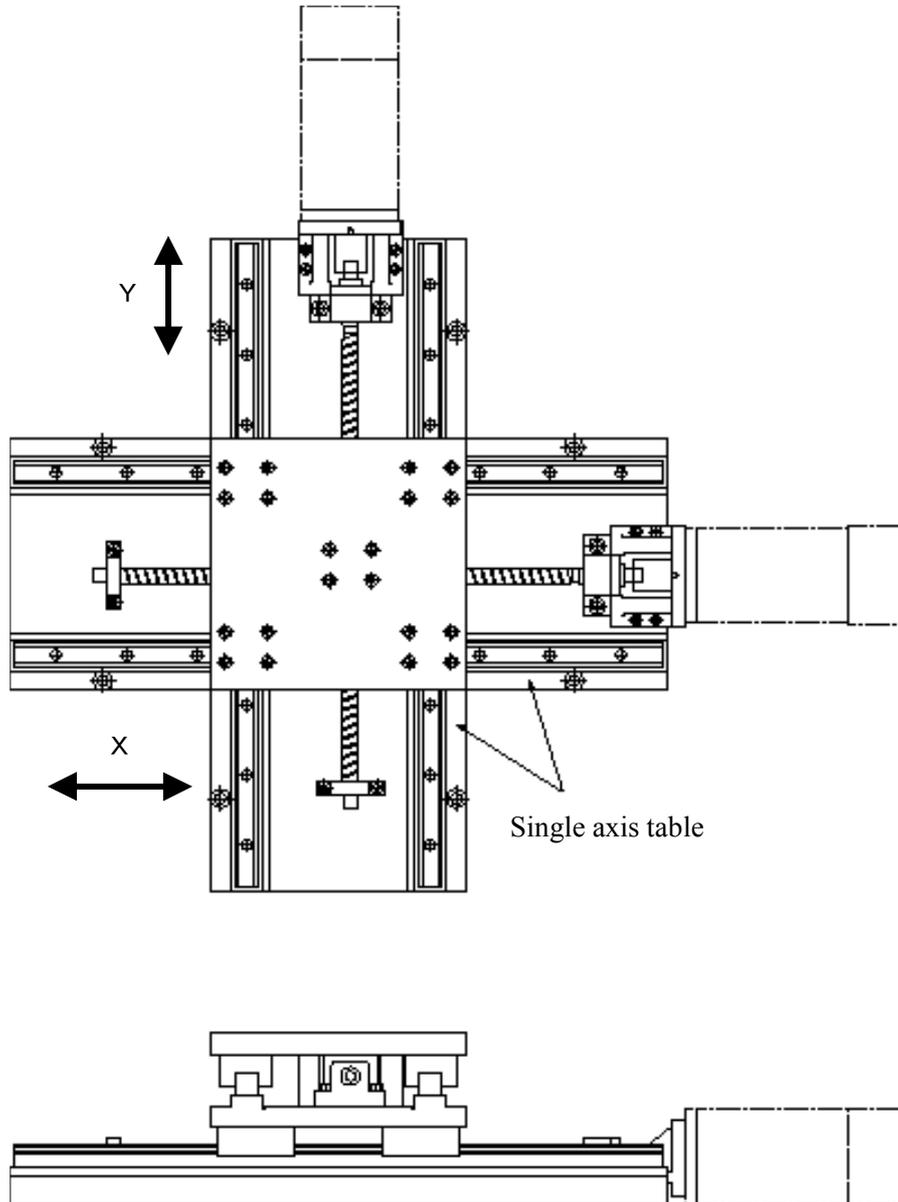
The linear guides are used as a guide to move a machine table in the direction of its X or Y axis accurately. Semiconductor manufacturing equipment or inspection apparatus that requires high precision in its positioning is one of their good application examples.

2 Low friction and resistance to wear

[Example 2] Machine tool

Horizontal
Machining center

Y

Z

X
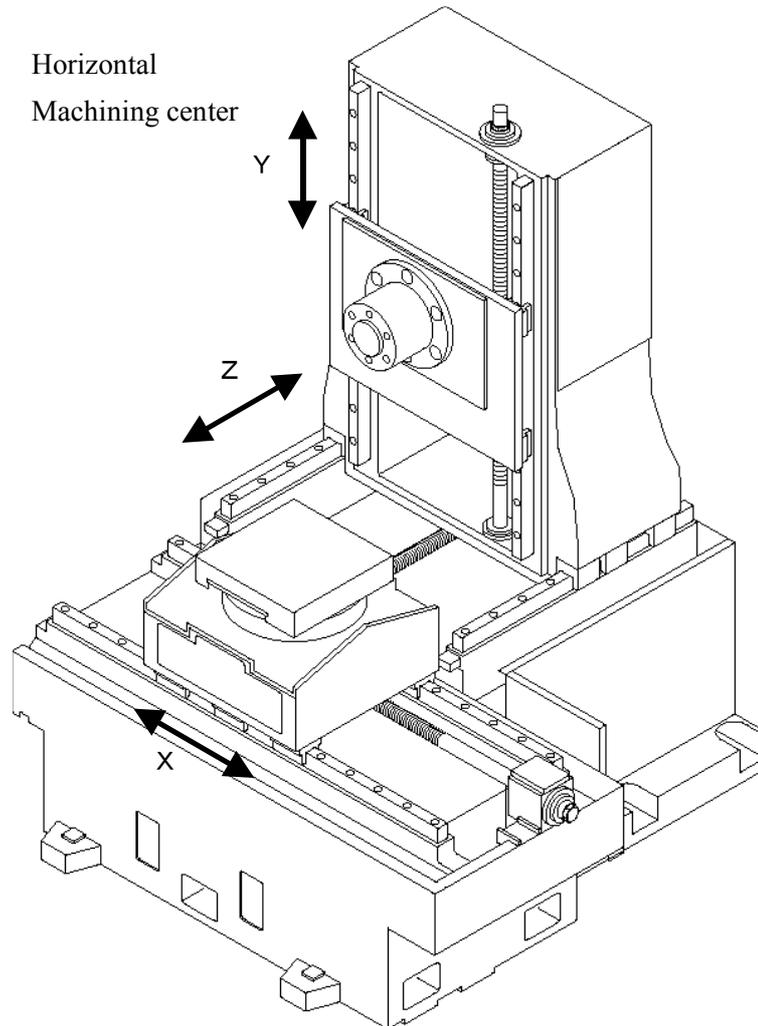
Linear guides are used to guide each table in the X, Y or Z direction in this application. For example, in the case of a machine tool for cutting, linear guides are selected to cope with temperature rise and durability issues associated with the needs to make feed speed (rapid traverse, cutting feed) ever faster, that cannot be accomplished by the sliding contact linear motion bearing. Besides, the use of linear guides will offer easiness in maintaining accuracy for a long time.

3 Low friction

[Example 3]

Linear guides are used to lessen the friction force to transfer machine glazed paper (150 tons).

[Example 4] Traveling material handling robot

Linear guides are used for a material handling robot that travels to load and unload the work.
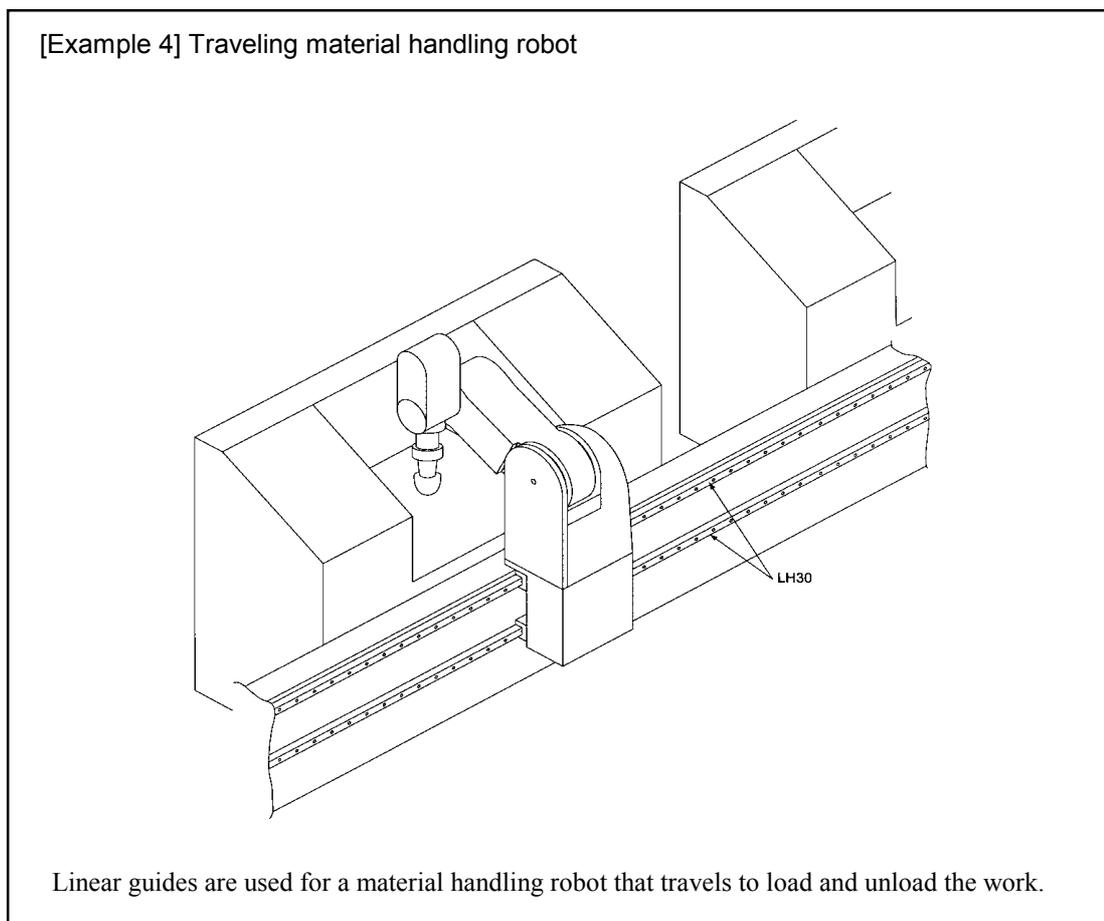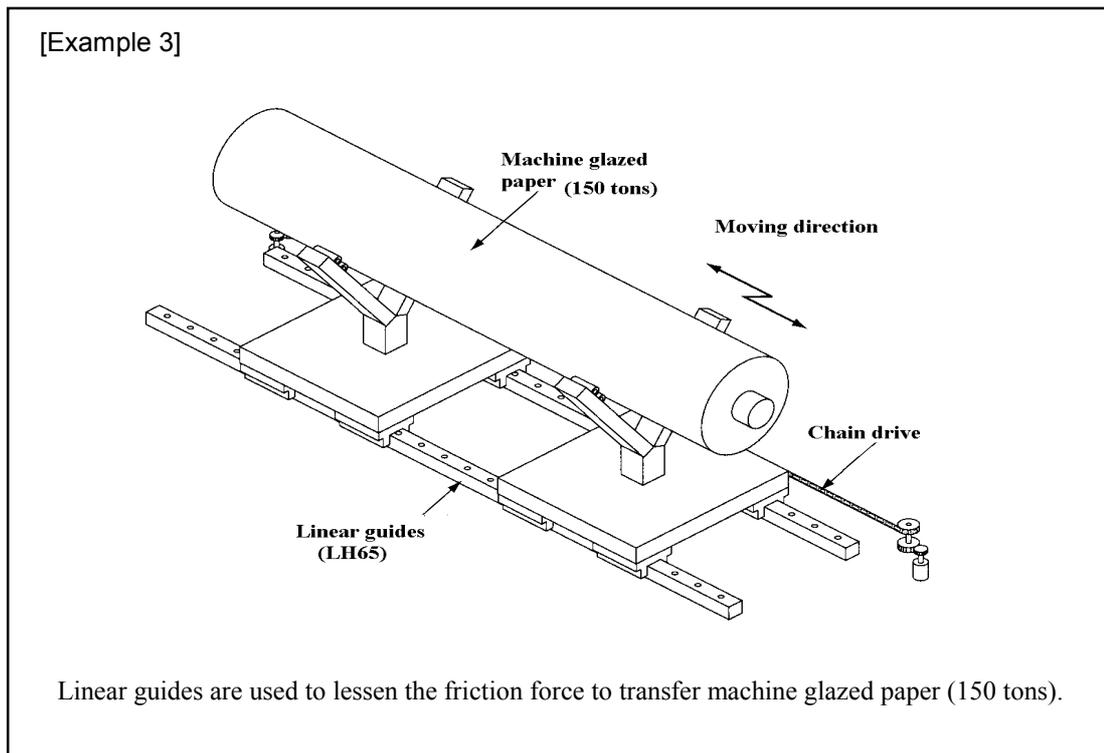
Section 3　Assembly and Mounting of Linear Guides

There are several rules you should know about assembling ball slides and rails. Here is the basic description extracted from the catalogues.

1 In case of interchangeable linear guides

● Since interchangeable ball slides are mounted on a provisional rail (an insertion jig) when they are delivered, you need to mount them onto the rails as shown in the figure below.

● Here, match position of the datum faces (a groove mark provided on a side face) of a rail and a ball slide as shown below.
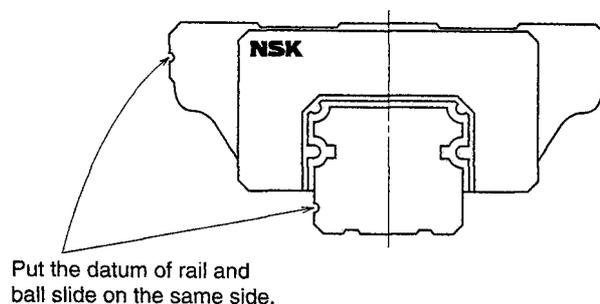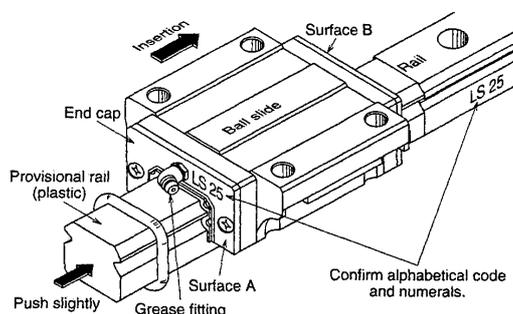
*Interchangeable linear guides : Thanks to precise control of positions of the ball grooves on a rail and on a ball slide, these components can be randomly matched (interchangeability).

2 In case of preloaded assembly (not interchangeable)

◆ **Mounting**

● NSK linear guides are furnished with a "groove mark" or an "arrow" (LE and LU series) to indicate the datum face of the rails and the ball slides. You are required to match the datum face (groove mark or arrow mark) of the rails with that of the ball slides.

● When two or more rails are used as a set, one rail must be used for the reference side, while the other(s) for adjusting sides. A code KL (called "KL mark") is added to the end of serial number of the reference rail, that is printed on the face opposite with the datum face, for easier identification.
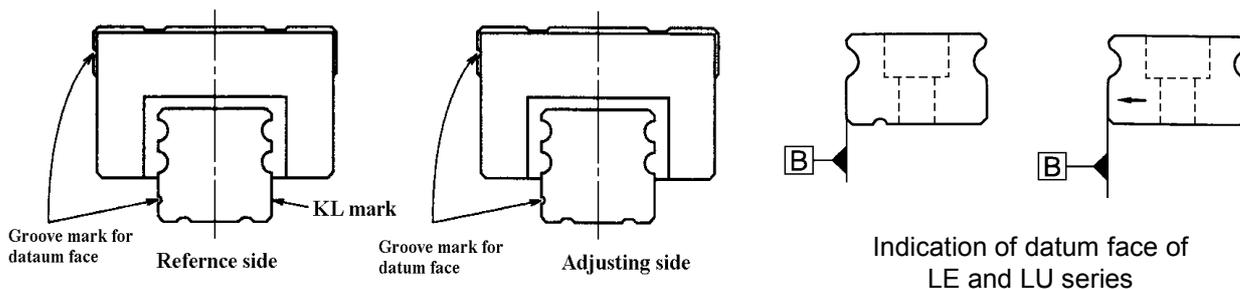
● When a linear guide is assembled by pressing its reference side rail and the datum surfaces of ball slides to the shoulders of machine bases, the distance (mounting width W2 or W3) between the datum face of the rail and those of installed ball slides are made to a minimum deviation. (Excessively large width variation could adversely affect the accuracy of an assembled table.)

Mounting width W2
(Popular arrangement of linear guides)

Mounting width W3
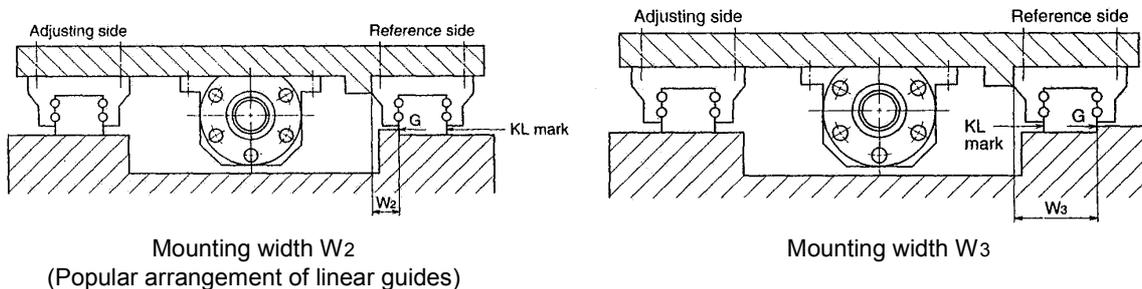
◆ Match marks for combining a rail and ball slides

● Each rail has its reference number and serial number marked on the side opposite from the datum face. Ball slides to be assembled onto individual rails have also their own serial numbers and arrow marks. The ball slides must be mounted in such a manner that the arrow marks point to each other.

● When two or more rails are used together and their reference numbers are the same, their serial numbers are to be laid out in sequence. Besides, the assembly with the smallest number among them is marked with "KL."

● When two or more rails are used together but their reference numbers are different, their serial numbers are the same. In such a case, it is necessary to pay due attention when removing ball slides from their rails since their numbers do not indicate any information on what ball slide came from which rail.
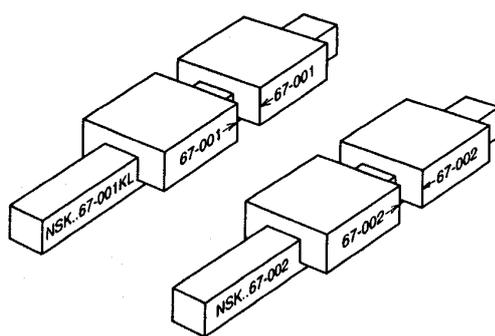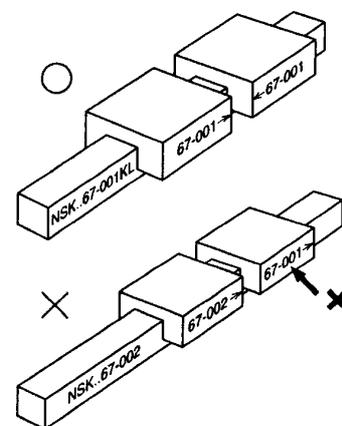
Same reference number (two rails)
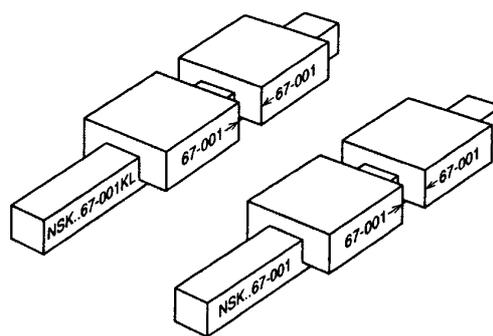
Different reference number (two rails)

◆ Mark for butting rails

● When the application length exceeds the maximum available length of a single rail, you are required to use butted rails.

● In the case of butted rails, match marks such as A, B, C, · · · are provided to the rails on their surfaces opposite with the datum faces. So, lay out the rails following those sequenced match marks.

[Remarks]

Keep the distance F, a pitch between two adjacent mounting holes of the rail as shown in the figure below. In the case of two rows of rails are used in parallel position, we recommend to arrange the rails so that the butting positions of each rails are staggered in order to avoid any changes in running accuracy at the spots of rail connection (a minute variation that occurs when the ball slides pass over such butted spots).
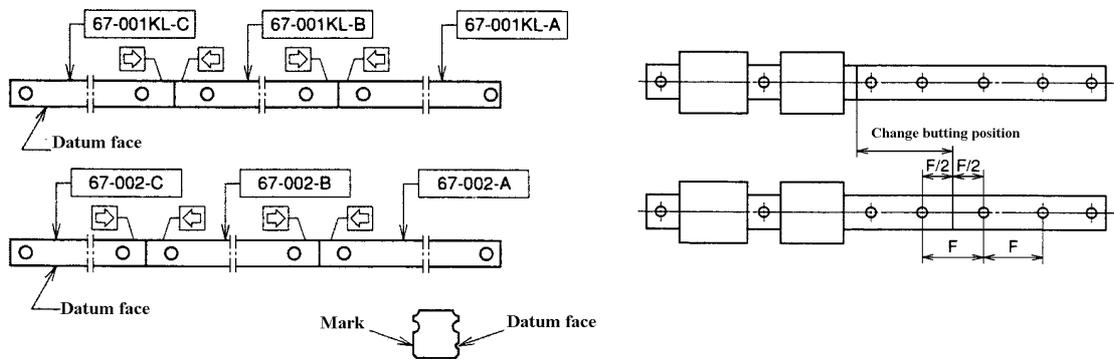
3 Manufacturing capacity of rail length (single rail)

The table below shows the maximum length of a rail. Where,

- The maximum available length varies with accuracy grade. (The higher in accuracy, the shorter the maximum available rail length.)

- When actual stroke exceeds the listed maximum length, you can still satisfy your needs by butting rails.

- As to the interchangeable LH or LS series, rails to be butted are also available.

Please contact our Engineering Department for such applications.

[Unit] : mm

Series	Size / Material	05	07	09	12	15	20	25	30	35	45	55	65	85
LH	Special high carbon steel					2000	3960	3960	4000	4000	3990	3960	3900	2520
LH	Stainless steel					2000	3500	3500	3500					
LS	Special high carbon steel					2000	3960	3960	4000	4000				
LS	Stainless steel					1700	3500	3500	3500	3500				
LA	Special high carbon steel						3960	4000	4000	3990	3960	3900		
LY	Special high carbon steel					2000	2000	2200	3000	3000	3700	3000	3000	
LE	Stainless steel	150	600	800	1000	1200								
LU	Special high carbon steel			1200	1800	2000								
LU	Stainless steel	210	375	600	800	1000								

Length limitation of LW series

[Unit] : mm

Series	Size / Material	17	21	27	35	50
LW	Special high carbon steel	1000	1600	2000	2400	3000

NSK

Chapter 2
Functional Characteristics
and
Handling of NSK Linear Guides

NSK Ltd.

Precision Machinery & Parts
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Lesson 1: Functional Characteristics

Section 1 | Accuracy of Linear Guides

1 Accuracy grade

Preloaded Assembly (Non-interchangeable)					Interchangeable
Ultra precision	Super precision	High precision	Precision	Normal	Normal
P3	P4	P5	P6	PN	PC

2 Definition of accuracy characteristics

Item	Definition
Mounting height H	Distance from A (bottom datum face of rail) to C (ball slide top face)
Variation of H	Variation of H in assembled ball slides to the rails for a set of linear guide
Mounting width W2 or W3	Distance from B (side datum face of rail) to D (side datum face of ball slides). Only applicable to a reference side rail.
Variation of W2 or W3	Variation of the width (W2 or W3) in ball slides assembled to a reference side rail.
Running parallelism of ball slide, face C to face A	Variation of face C (ball slide top face) to face A (bottom face of rail) when ball slide is moving.
Running parallelism of ball slide, face D to face B	Variation of face D (side datum face of ball slide) to B (side datum face of rail) when ball slide is moving.

◆ **Mounting height H, Mounting width W2 and W3**

● Mounting width varies depending on how you take the datum face of the ball slides to be mounted onto the reference side rail (that has a KL mark on it).

● There are two different mounting widths, W2 and W3. You require selecting one of them based on the construction of your machine, or particular mounting preferences.
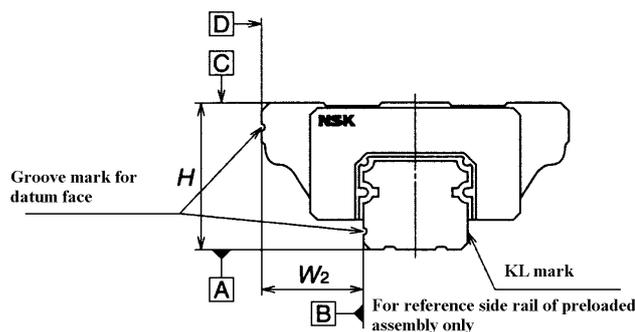
Mounting width W2
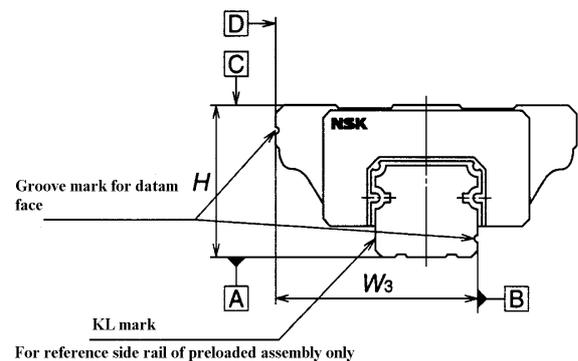
Mounting width W3

● Mounting example of Width W2 and W3
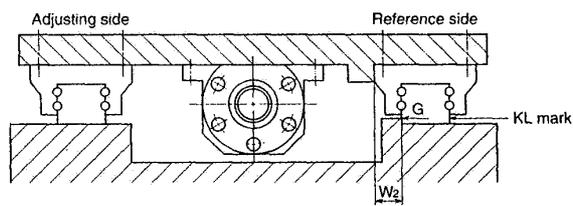
Mounting width W2
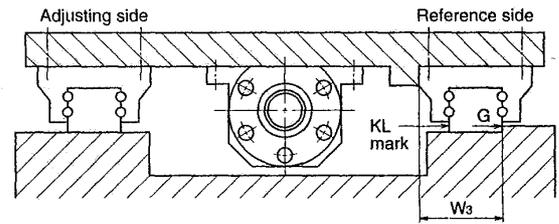
Mounting width W3

◆ **Running parallelism of ball slide**

Running parallelism of ball slide is the variation of distance between the datum faces of rail and ball slide when ball slide is moving.
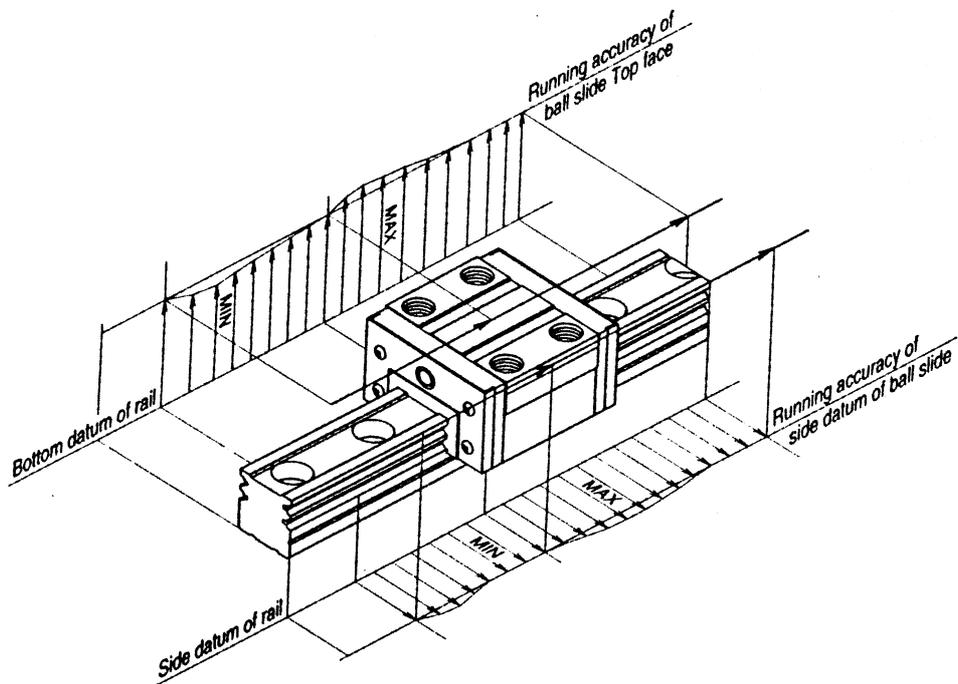
| Section 2 | Preload of Linear Guide |

◆ What is preload?

- We squeeze over size balls into ball tracks to create elastic deformation on balls and ball grooves as if an external load is working prior to apply actual load to a ball slide.
  → Preload.

- We control the preload by very minute change of the ball size.

- Increase in preload enhances rigidity of the linear guides.

Ball

Ball slides

Rail

Ball groove
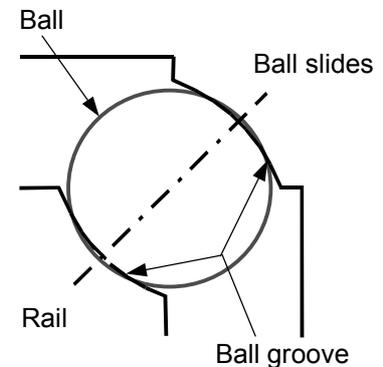
- Different preloading levels are provided with the linear guides, and specific preload (preload force) is applied to respective series and model sizes.
    ◊ Preloaded assembly : Z0 (fine clearance) ~ Z4 (heavy preload)
    ◊ Interchangeable type : ZT (fine clearance) and ZZ (slight preload)

✎**Notes : What is elastic deformation?**

When removing an applied force that has caused deformation, the deformation disappears. When you grasp a rubber ball, it deforms. But, when you release it, it recovers its original shape. This type of deformation is called "elastic deformation."

◆ Purpose of preload (Effects)

- It eliminates internal clearance between a rail and a ball slide. (→ Zero backlash)

- It minimizes elastic deformation caused by external force.   (→ Enhances rigidity)

◆ Principle of preload

A typical curve of linear guide deformation versus load is shown by the figure below left. It can be seen from the figure that as the load is increased uniformly, the increasing rate of deformation declines. Therefore, it would be advantageous with regard to deformation under load to operate above the "knee" (inflection point) of the load-deformation curve. Preloaded linear guide realizes this condition. As shown in the figure below right, the preloading tends to reduce the deformation of linear guides under additional load.

[Z0 to Z4 are the preload code. Z0 (fine clearance) is not preloaded, while Z4 (heavy preload) is applied the highest preload.]
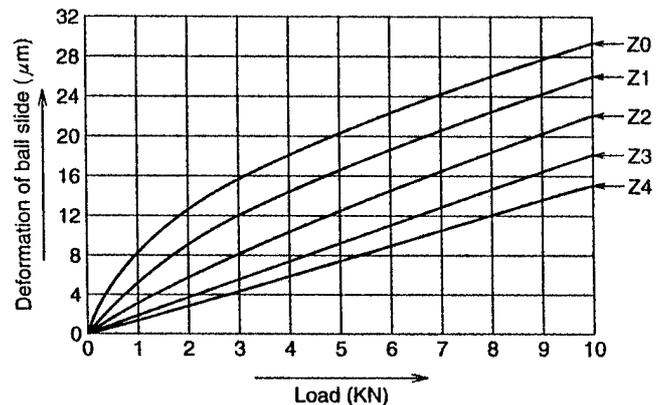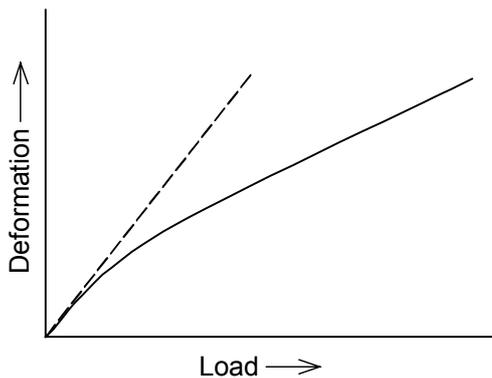
Deformation of preloaded LY35

Section 3 | Rigidity of Linear Guides

Rigidity is a "characteristics" that defines resistance (within a range of elastic deformation) to its deformation when external forces act on a linear guide, or a "level" of such resistance. If taking a coil spring as an example, it is equivalent to their spring constant. For rigidity of respective series, sizes or preloads, look into the catalogues.

Rigidity: Higher   Rigidity: Lower
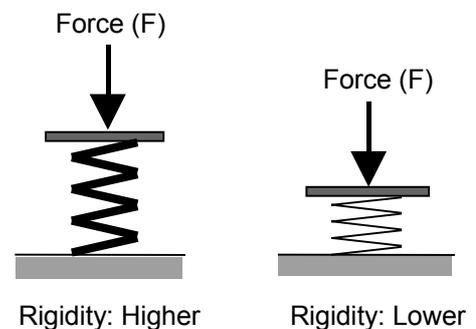
Lesson 2: Designs and Characteristics of Ball Grooves

Now you will learn about the profile and characteristics (functions) of ball grooves of NSK linear guides so that you will be capable of explaining what their aspects of the NSK guides are superior to those of the competition.

| Section 1 | Profile of Ball Groove for Linear Motion Guide Bearings |

Profile of ball groove for the linear rolling guide is generally classified in three types as shown below.

Gothic arch groove
(Consists of two arcs centered at O1 and O2.)

Circular arc groove
(Consists of one arc.)

Offset gothic arch groove
(Gothic arch groove of a rail is offset with that of a ball slides.)
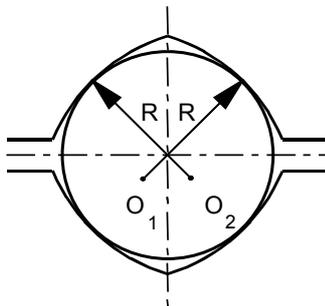
- Easy to control groove profile accuracy (*)
- Complete four-point contact
- Higher friction forcecompared to other types
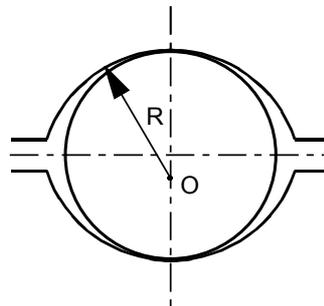
- Difficult to control groove profile accuracy(*)
- Two-point contact
- Low friction force
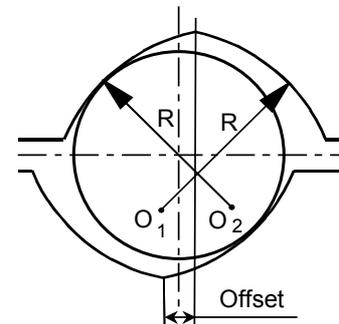
- Easy to control groove profile accuracy
- Two-point contact (four-point contact) (*)
- Low friction force (high friction force) (*)

Groove profile of NSK linear guides
(For the series with 1 groove on a side of rail and ball slide)

Groove profile of NSK linear guides
(For the series with 2 grooves on a side of rail and ball slide)

(*) We will discuss details of item with an asterisk (*) in Section 2.

[Note] The offset is the difference in groove pitch (distance between centers of two grooves) of a rail and a ball slide.

Section 2 | Characteristics of Gothic Arch Ball Groove

1 Groove designs to meet application

1) With a smaller offset (LY series):

● In the range of lighter preloads (~Z2)　　: In the state of two-point contact
　　　　　　　　　　　　　　　　　　　　　　$\rightarrow$ Low friction

● In the range of heavier preloads (Z3 and Z4)　: In the state of four-point contact
　　　　　　　　　　　　　　　　　　　　　　(Unequal contact pressure on four points)
　　　　　　　　　　　　　　　　　　　　　　$\rightarrow$ The number of contact points is doubled.
　　　　　　　　　　　　　　　　　　　　　　$\rightarrow$ Higher rigidity
　　　　　　　　　　　　　　　　　　　　　　　　Higher load capacity
　　　　　　　　　　　　　　　　　　　　　　　　High friction force
　　　　　　　　　　　　　　　　　　　　　　　　High vibration-damping capability

2) With a larger offset (LH, LS and LW series):

● In the all range of preloads　　　　　　　: In the state of two-point contact.
　　　　　　　　　　　　　　　　　　　　　　$\rightarrow$ Low friction force
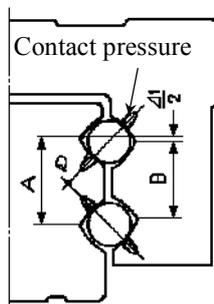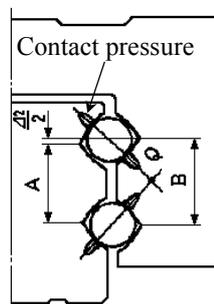
[Offset: large]　　　　[Offset: small; Preload: light]　　　　[Offset: small; Preload: heavy]
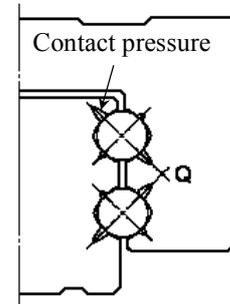
In state of 2 points contact　　　　　**In state of 4 points contact**

• Low friction
• Applications:　Measuring equipment, Robot, Transporting apparatus, Non-cutting machine tools

• High rigidity
• High friction $\rightarrow$ High damping
• Application: Cutting machine tools

— 6 —

2 Groove designs to meet intended functions

By minutely modifying the inter-groove pitch on a rail and that on a ball slide (offset), you can have either a self-aligning design (DF) or a high rigidity design (DB).
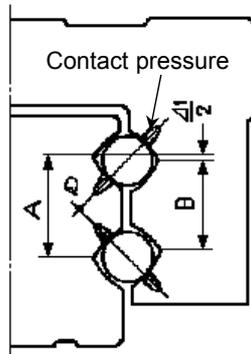
Self-aligning design (DF configuration)

- Same as the DF configuration for angular contact bearings, the cross point Q of the two contact lines is inside.
- The particular design is used where absorbing capability of mounting errors is required.
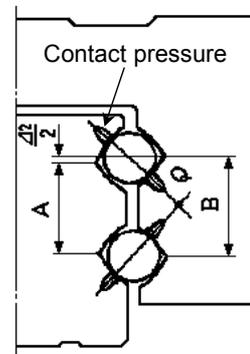
High rigid design (DB configuration)

- Same as the DB configuration for angular contact bearings, the cross point Q of the two contact lines is outside.
- This design is used where rigidity is primarily required (e.g. machine tools) or where only one rail is used.

◆ Difference between DF and DB configuration

Given here is an explanation on differences in moment load rigidity (self-aligning property) between DF and DB configuration. As shown in the following illustrations, the length of an arm of the reaction force to the moment load M has such a relationship as $l_1 \fallingdotseq 2 \times l_2$. Thereby, the self-aligning design (DF) is lower in moment load rigidity. Hence, it has its self-alignment property about twice as large as the DB design.
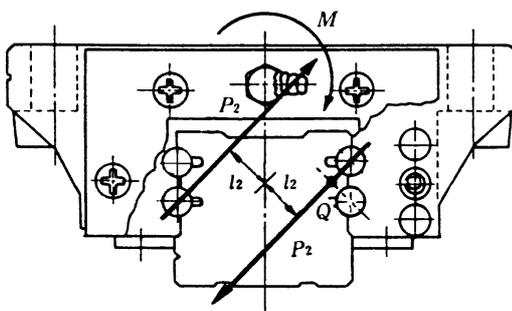
Self-aligning design (DF configuration)
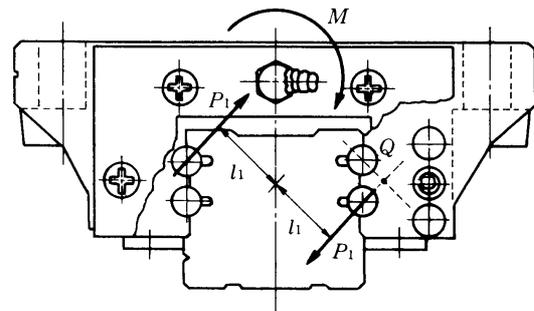
High rigid design (DB configuration)

3 Superb capacity for impact load

Offset gothic arch groove   **Circular arc ball groove**

Contact of balls under normal load
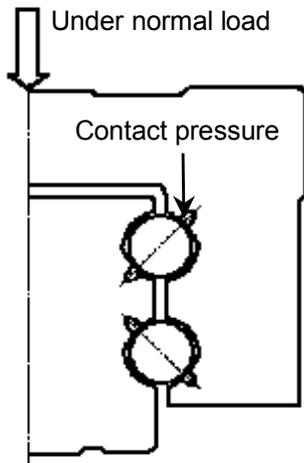
Under normal load

Contact pressure

Sustained by 2 rows
Usually, two rows of upper grooves bear the load.

Under Normal load

Contact pressure
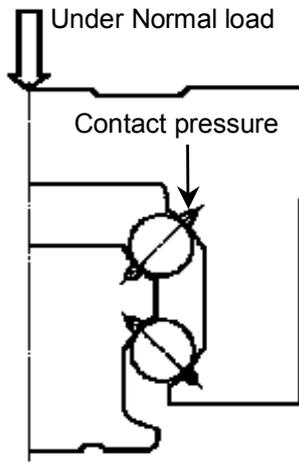
Sustained by 2 rows
Usually, two rows of upper grooves bear the load.

Contact pressure

Impact load

Sustained by 4 rows
Two rows of lower grooves will join to support impact load.
(The figure above shows that contact direction of ball changes when impact load is applied.)

Contact pressure

Impact load

Development of clearance
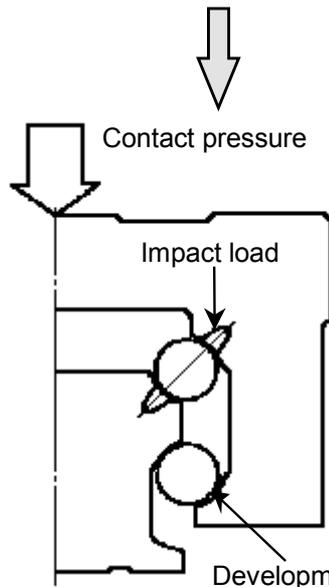
Sustained by 2 rows
Even in case of impact load two upper rows bear the entire load.

Contact of balls under impact load

Offset gothic arch grooves exert an impact-resistant property since those surfaces that don't usually bear any load will newly join to bear the loads when high load like an impact load is applied.

✍Notes : What is differential slip

When a ball makes one rotation, there arises a slip on a contact surface of ball and ball groove caused by a difference in the length of a circumferential travel between the inside (πD_1) and outside contact diameters (πD_2) as shown in the following figures. This slip is called "differential slip." When the differential slip is larger, a ball rotates while it is slipping more, which results in a higher friction resistance because the coefficient of friction increases.
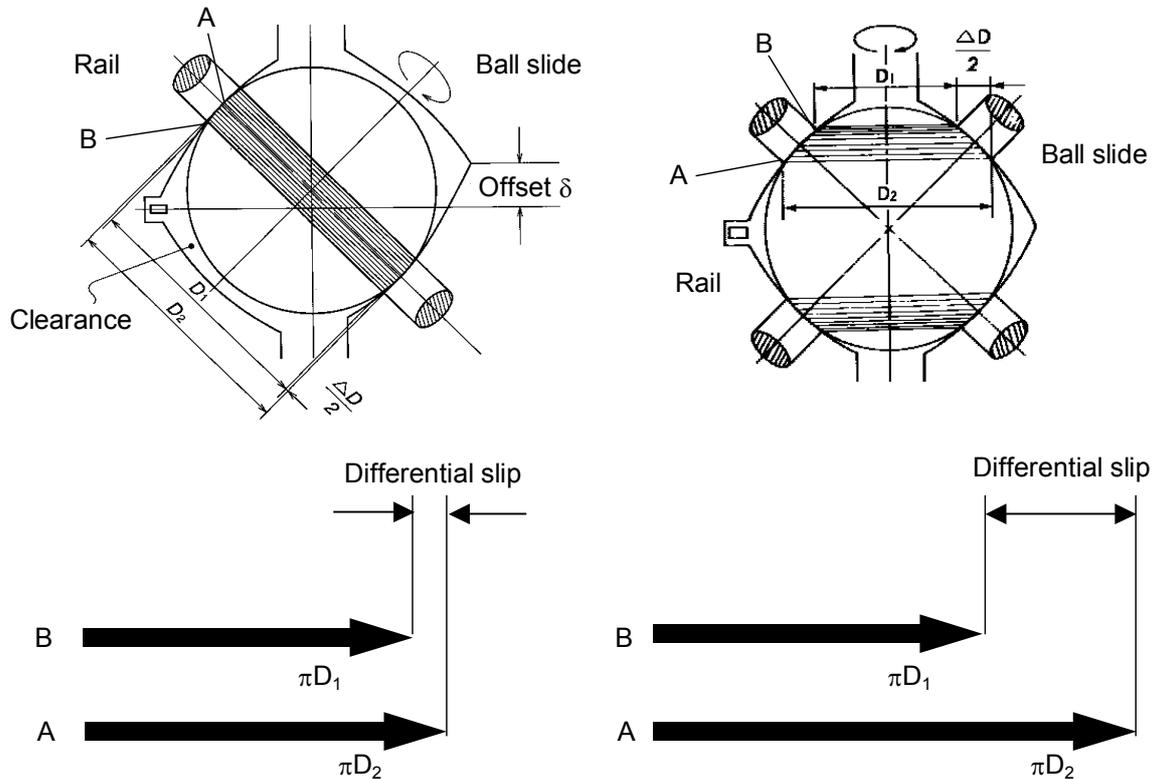
4 Assurance of functional property

■ Functional properties (rigidity, life, running accuracy, etc.) of linear guide are depending on how precisely the profile and the dimensions of ball grooves are formed. In other words, overall performance of a linear guide is assured only when those characteristics have been precisely measured and kept under control.

■ Methods of grinding a rail and of measuring the dimension between two grooves are shown in the following illustrations. Since the rail is ground with two grinding wheels (both right and left sides simultaneously), the accuracy of groove profile and vertical distance between two grooves will depend on how precisely the profiles of grinding wheels are formed and maintained. Lateral groove distance W is determined by how much the grinding wheels are fed into. Thus, if the dimension W is measured properly, all accuracies of ball grooves can be perfectly controlled.

**Grinding of datum face
and ball grooves**

**Measuring accuracy
of ball grooves**

Gothic arch groove

Circular arc groove
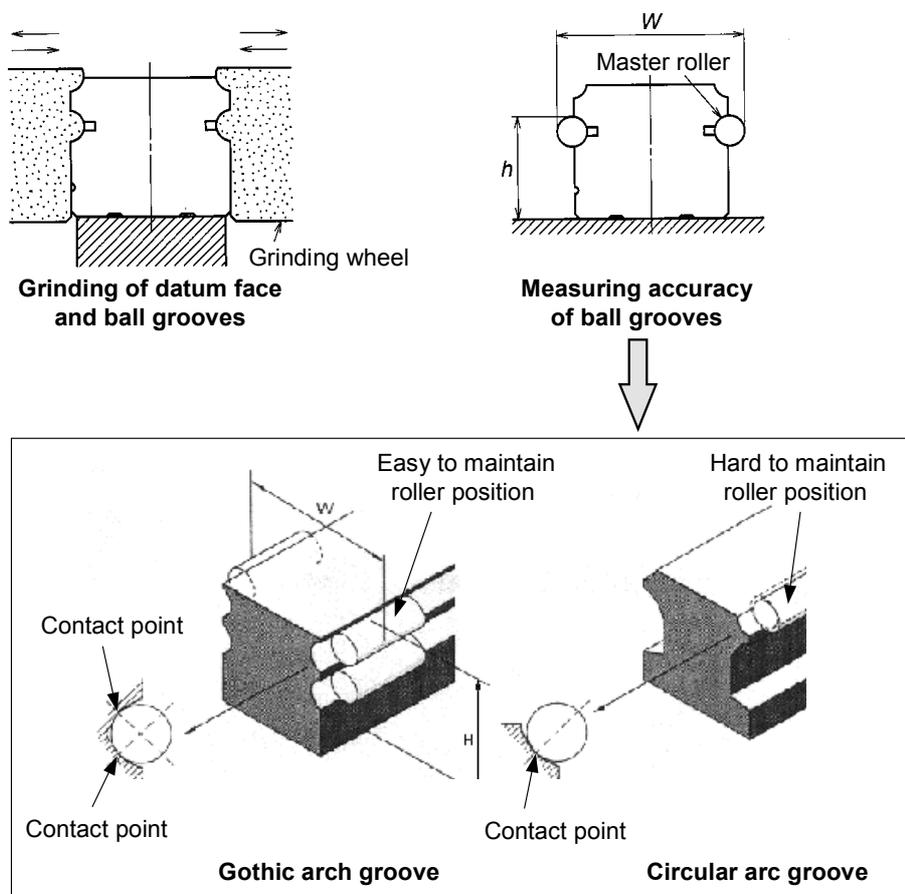
■ As clearly shown in the above illustrations of the concept how to measure a groove position;

1) In case of Gothic arch grooves, since a master roller comes into contact with the groove on two points, it will stay in its position stably, which makes a highly accurate measurement easier. Consequently,
   → Rails and ball slides can be matched randomly (interchangeability), as represented by the LH and LS series.
   → Also, in the case of multi-point contact construction like the LY series, a stable roller contact can be maintained.
2) On the other hand, as the circular arc grooves cannot assure the stable positioning of the master rollers, it is extremely difficult to perform an accurate measurement.

Needless to say, these matters are exactly applicable to the grooves of ball slide.

Lesson 3: Dustproof and Lubrication for Linear Guides

Use conditions are so diverse as the linear guides have a fairly wide range of application. In order to assure that NSK linear guides can be used for a period of their inherent life, a dustproof structure and lubrication appropriate to a specific environment are required.

Section 1 | Dustproof Parts for Linear Guides

1 Standard specification

To prevent foreign particles from entering the inside of a ball slide, it is provided with end seal on its both ends, and a bottom seals on its bottom.

End seal

Bottom seal
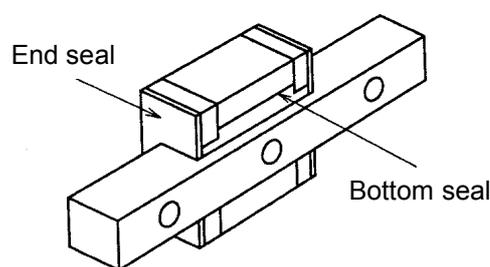
2 Double seals and protectors

◆ Double seals

● Two end seals are assembled to one end of a ball slider for higher sealing capability.

● "Double Seal Set," a set of end seals for addition to a standard linear guide, is available. For more details, see the catalog (No. E3155, page A161).

● When a double seal set is used, the total length of ball slide will become longer than standard specification. Thus, take due consideration on the dimensions associated with ball slide mounting area and stroke.

◆ **Protectors**

● Protectors, which are attached to the outside of end seals, prevent high temperature dust particles, such as welding spatters, or hard foreign materials from entering the ball slides.

● "Protector Set," a set of protectors for addition to a standard linear guide, is available. Refer to the catalog (No. E3155, page A162) for more details.

● When a protector set is used, the total length of ball slide will be longer than the standard specification. Thus, take due considerations on the dimensions associated with ball slide mounting area, and stroke.
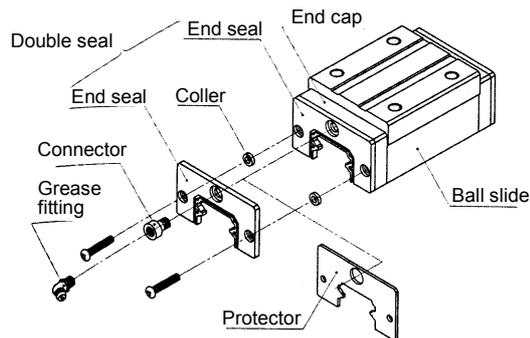
Models excluding LY series
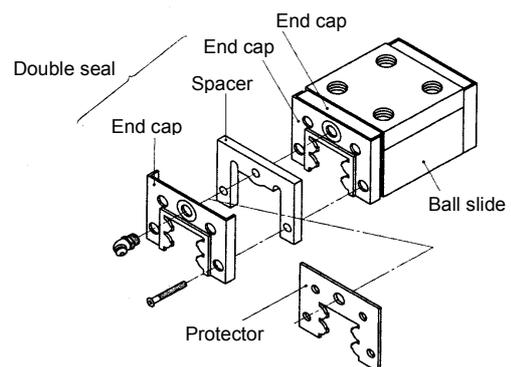
LY series

3 Caps for bolt holes of rails

● After mounting rails onto the machine base, all bolt holes are plugged by caps to allow no depressions on the top surface of the rail. Such depression, may collect foreign particles, and then, allow them entering the inside of the ball slide.

● Highly oil-resistant and abrasion-resistant plastic material is used for caps as a standard.
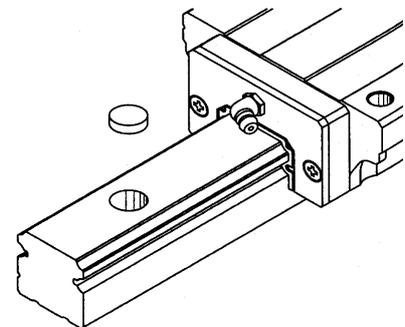
4 Inner seal

- Inner seals are provided to protect ball-contact surfaces from a slight amount of those foreign particles that the end seals mounted on the ends of a ball slide couldn't arrest.

- Since the inner seals are assembled inside a ball slide the overall dimensions and profile don't differ from those of the standard.

- Applicable models: LH20 ~ 85, LS20 ~ 35, LA25 ~ 65, and LY30 ~ 55.

Inner seal
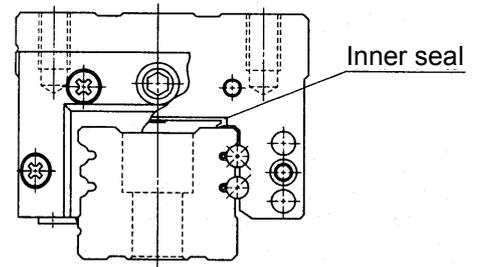
5 Bellows

- Bellows are used to protect the entire part of a linear guide when it is used in an environment abundant in foreign particles.

- Special bellows are available to LH, LS, LA, LY and LW series. For more details, refer to catalogue (No. E3155, page A164 to A171) for more details.
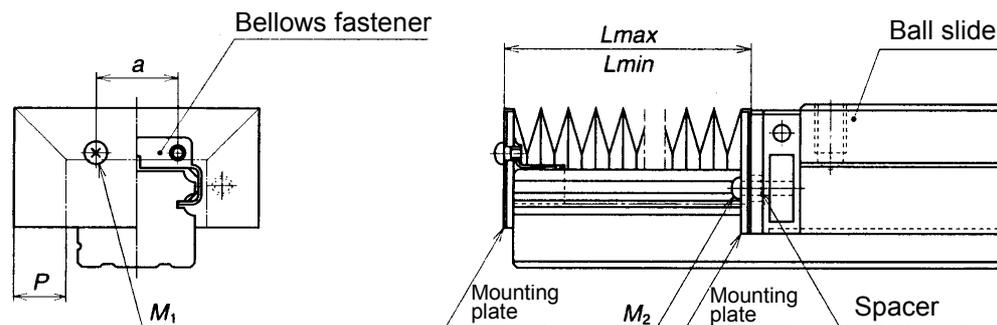
Example of bellows assembly (for LH and LS series)

6 High performance seal

- Three-layer lips to attain high dust-tight function make possible to keep the inside of a ball slide free from foreign particles, and also help to retain lubrication grease inside the ball slides.

- Wire retainers that are used to secure balls are removed so that the groove for the wire could be removed from the bottom of rail grooves for further increase in the dust-proof property. (Accordingly, due cares must be exercised so that balls would not fall apart when a ball slide is removed from its rail.)

- "NSK K1™" lubrication unit (see 7) is furnished for higher dust protection and durability as a standard.

- Effects: As compared with existing standard end seals, in-house evaluation tests suggest that the High Performance Seals can:
  1) Reduce the amount of foreign particles passing through the seals to less than one tenth.
  2) Extend the life of linear guide by more than two times.

- Applicable series: LH25, 30, 35, and 45 (for LH25 and 30, available to material of stainless steel)

- Accuracy grades and preload codes are provided in the same manner as the standard products. Dynamic friction force is slightly higher.

- Application examples: Typically used in an atmosphere where a lot of foreign particles exist, such as woodworking machines, laser beam processing machines, welding processing lines, etc.

High performance

Appearance   AA section
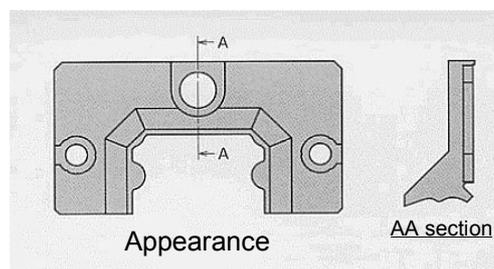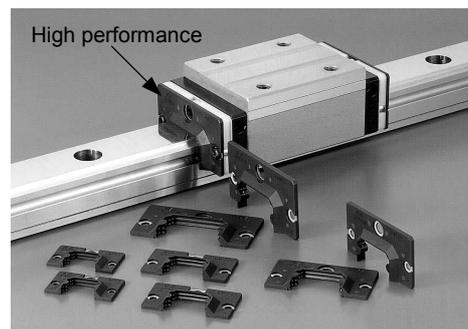
7 "NSK K1™" Lubrication Unit

Although this is not related to dustproof, some description are yet to be given here since this also helps to extend the life of linear guides used in adverse environment.

- Polyolefin resin that contains 70 weight % of lubricant among its molecules is used. The resin is formed into the shape of a seal.

- This is a completely new type of lubrication unit that can continuously supply fresh lubricant to contact surfaces of balls.

- Most useful in the following environment or situations:
  1) In mechanical environment where replenishment of lubricant is difficult.
     → Equipment on production lines (maintenance-free)
  2) Only a limited amount of lubricant can be applied.
     → Clean room equipment, medical apparatus
  3) Lubricant is washed off.
     → Food processing machine
  4) There are fine particles that absorb lubricant.
     → Woodworking machine
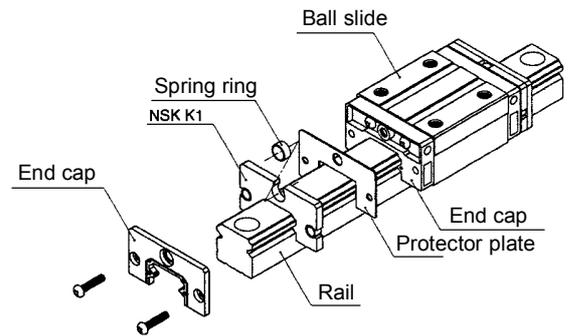
Section 2 | Lubrication

1 Merits and demerits of grease and oil lubrication

Items	Grease Lubrication	Oil Lubrication
Housing construction Sealing system	Can be simplified.	Rather complicated. Thereby, due cares are required for maintenance.
Cooling function Cooling effect	None	Effective in radiating heat (in the way of a circulated oil).
Lubricant fluidity	Inferior	Excellent
Lubricant replacement	Rather complicated.	Relatively easy.
Filtering of foreign particles	Difficult	Easy
Lubricant leakage and contamination	Not messy even when leakage has happened.	Not suitable for environment where contamination caused by any oil leakage must be avoided.

When thinking only about lubrication per se, oil lubrication is superior. However, (1) since grease lubrication does not need for any complicated lubrication system (piping system, a pump, etc.), (2) it can be used for a small lubrication amount, the grease lubrication is widely used.

2 Precautions for oil lubrication

In some cases of particular assembly configurations, due cares must be taken for oil path design. In the cases of such configuration as shown below, oil tends to flow only in the lower part, and does not reach the upper part sufficiently because lubrication oil is not pressurized. The oil is simply supplied by the gravity. Thus, ball grooves in the upper part may suffer from poor lubrication. Therefore, some countermeasures are needed to provide a special design to oil paths inside the ball slides. (Grease lubrication does not bring in any problems of this kind.)

[Example 1]
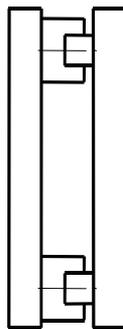
[Example 2]
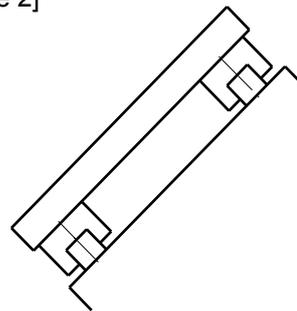
[Example 3]

No lubrication problem for horizontal setting.
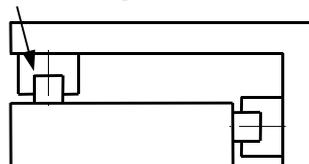
[Example 4]
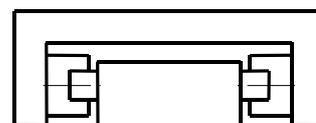
③ **Grease unit**

For the purposes of lubricating linear guides, both various types of grease (80 g) packed in bellows containers and a manual grease gun are available.

- ● Easy in use. You can mount a grease container into the gun only by one single step.

- ● Also, when it won' be used for a long time, remove the container from the grease gun and cap it for storing to prevent deterioration of grease.

Grease	Application	Color of container
NSK grease AV2	Heavy duty	Brown
NSK grease PS2	High speed, light load	Orange
NSK grease LR3	High speed, medium load	Green
NSK grease LG2	Clean environment	Blue
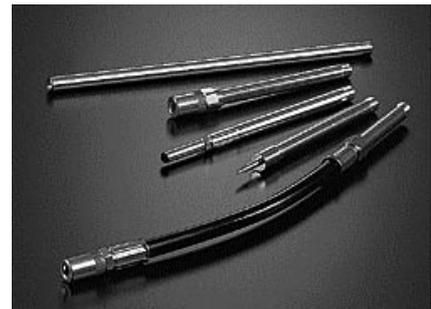
Lesson 4: Precautions on Handling Linear Guides

This section describes the essential matters to be attended that are necessary for proper handling of the linear guides.

Section 1 | Precautions on Usage

- The allowable maximum speed for the standard specification is 100 m/min. If linear guides are used at a higher speed than that, their parts for ball re-circulation, such as end caps, must be changed into high-speed specification. When high-speed type end caps are used, their allowable speeds are enhanced as follow.

    ◊ Type 15 ~ 35   : 300 m/min

    ◊ Type 45 and 55 : 200 m/min

    ◊ Type 65   : 150 m/min

- The maximum operating temperature is limited to 80 °C. Accordingly, special designs will be needed whenever the user's specification shows a higher temperature than that.

Section 2 | Storage

- Ask the users to store the linear guides as originally packed by NSK until their use. If internal packaging is ripped off or damaged, dust entry or rusting could take place.

- If rails are stored improperly in terms of their storage positions, they might bend. It is necessary to apply appropriate supports to keep its storing position horizontally.

NSK

Chapter 3
Selection of Linear Guides
(Primary Course)

NSK Ltd.

Precision Machinery & Parts
e-Project Team

Lesson 1: Outline of NSK Linear Guides

NSK linear guides are available in various series that have numerous ball slide models and standardized dimensions to cover every kind of application. Here, we will describe the outlines of NSK linear guides so that you can offer the most appropriate choices to users.

Section 1   Series of NSK Linear Guides

	High vertical load carrying capacity type	Self-aligning type	LH series	Preloaded assembly / Interchangeable type — • Special high carbon steel: All model • Stainless steel: Model No.:15, 20, 25 and 30 only
			LS series	Preloaded assembly / Interchangeable type — • Special high carbon steel: All model • Stainless steel: All model
		High moment load carrying type (Wide rail type)	LW series	Preloaded assembly / Interchangeable type — • Special high carbon steel: All model
NSK Linear Guides	Four directional iso-load carrying type	High rigidity type	LY series	Preloaded assembly — • Special high carbon steel: All model
		Super rigid type	LA series	Interchangeable type — • Special high carbon steel: All model
		High moment load carrying type (Wide rail type)	LE series	Preloaded assembly / Interchangeable type — • Stainless steel: all model
		Miniature	LU series	Preloaded assembly — • Special high carbon steel: All model (excluding 07AL and 09TL) Interchangeable type — • Stainless steel: All model (For LU15, special high carbon steel available)
		Light weight miniature	LL series	Preloaded assembly — • Stainless steel
	Linear guides for special application	Heat resistant		
		S1 series		
		MF series		

— 1 —

1 High vertical load carrying capacity type

This type has a higher rigidity and a load carrying capacity in its vertical direction compared to those in a lateral direction.

◆ Self-aligning type

- This type has high self-aligning capability to absorb mounting error.

◆ High moment load carrying type

- Wide rail width offers high rigidity and load capacity in rolling moment direction.

- Best suited when only single rail is in use for guiding a driving axis.

◆ Preloaded assembly (non-interchangeable)

- Rail and ball slide are assembled into a set, guaranteeing its specific functions.
  (It will be sold as an assembled set.)

- Rails and ball slides are not interchangeable.

◆ Interchangeable type

- Rails and ball slides can be assembled randomly. (interchangeable rails and ball slides)

- Rails and ball slides are standard stock parts, and can be purchased individually.
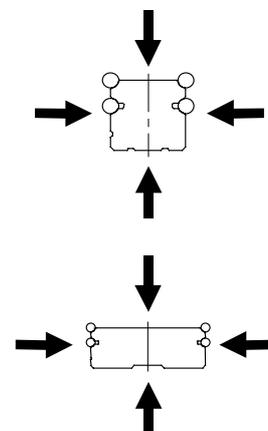
2 Four directional iso-load carrying type

This type has equal rigidity and load capacity in both vertical and lateral directions.

◆ High rigidity type

- Designed to have highly rigid contact condition between steel balls and ball grooves.

- Mainly used for machine tools.

◆ Super rigid type

- There are a total of six ball grooves, and their contact shape with steel balls is designed to assure extremely high level of rigidity.

- Manly used for machine tools.
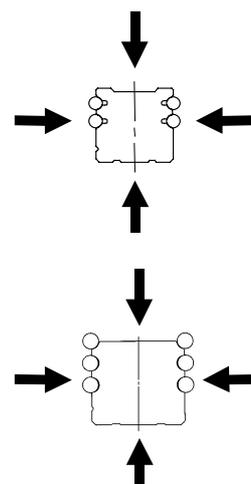
3 Linear guide for special application

These are the types provided with special specifications, suitable to cope with special environment or for promoting a maintenance-free preparedness. We discuss more details in Lesson 3.

Section 2   Accuracy Grade and Preload Setting for Each Series

1 Accuracy grade

We specify accuracy grade appropriate to the features of respective series of the linear guides.

Series \ Grade	Preloaded assembly (Non-interchangeable)					Interchangeable
	Ultra precision P3	Super precision P4	High precision P5	Precision P6	Normal PN	Normal PC
LH	✓	✓	✓	✓	✓	✓
LS	✓	✓	✓	✓	✓	✓
LA	✓	✓	✓	✓		
LY	✓	✓	✓	✓		
LW			✓	✓	✓	✓
LE			✓	✓	✓	✓
LU		✓	✓	✓	✓	✓
LL					✓	

2 Classification of preload

Each series of linear guides has its unique preload classification suited to its own characteristics.

preload \ Grade	Preloaded assembly (Non-interchangeable)					Interchangeable	
	Heavy preload Z4	Medium preload Z3	Light preload Z2	Slight preload Z1	Fine clearance Z0	Slight preload ZZ	Fine clearance ZT
LH		✓		✓	✓	✓	✓
LS		✓		✓	✓	✓	✓
LA	✓	✓					
LY	✓	✓	✓	✓	✓		
LW		(✓)		✓	✓		✓
LE				✓	✓		✓
LU				✓	✓		✓
LL					✓		

Note: Medium preload Z3 of LW series is available to LW35 and LW 50 only.

3 Combination of accuracy grade and preload setting

The table below shows available combination of accuracy grade and preload.

		Accuracy grade	Preload code
Preloaded assembly		P3 ~ P6	Z4 ~ Z0
		PN	Z1, Z0
Interchangeable		PC	ZZ, TT

Lesson 2: Let's Select a Linear Guide!

Now let's select one linear guide that meets the use conditions and user's special requirement.

Section 1 Selection Flow Chart

The following is an example of primary steps to make an optimum selection with an emphasis upon those standard stock series that are favorable in both their lead times and prices.
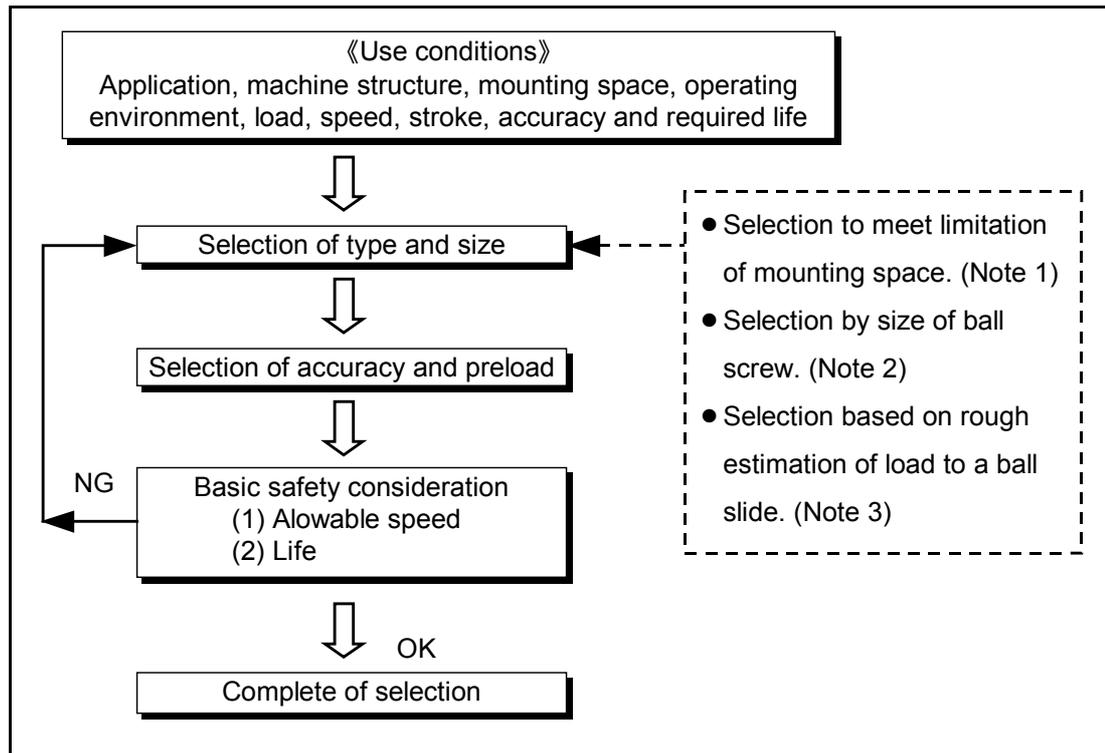
Note 1 : There might be limitations on mounting space of linear guide because of structural restrictions on the machine.

Note 2 : In case of a ball screw drive, it is advisable to choose a linear guide with its model number same as or closest to the ball screw shaft diameter. (Based on experience, and for the sake of attaining good machine balance.)

Note 3 : Applied load per ball slide herein shall be calculated simply by dividing total applied load by the number of ball slides. Then select the model number from Figure I-3 and 4 in the catalog "Precision Machine Components(No. E3155, page A19)."

Section 2 | Information from the Users (Use Conditions and Requirements)

1. Application

This is the information on the type of machine (application) like machine tools, transporting systems or measurement apparatuses for which linear guides are to be used. Generally, such information is very useful to select appropriate linear guides.

2. Machine structure

The information covers the structure of machines and their relevant aspects of construction such as dimensions around the place where linear guides are mounted to, positions and directions of external forces, etc. This is compulsory information for selecting particular linear guides.

3. Applied loads

These are the loads applied to the linear guides, which usually consist of self-weight of a table, weight of transported objects, and/or forces that are working on a machine tool. The loads are normally applied vertically or laterally against motion axis.

4. Speed

This means a relative speed of the table (with the ball slides) against the rails. It is expressed as, for example, 100 m/min.

5. Stroke

This means a travel distance that a table mounted on ball slides is required to make.
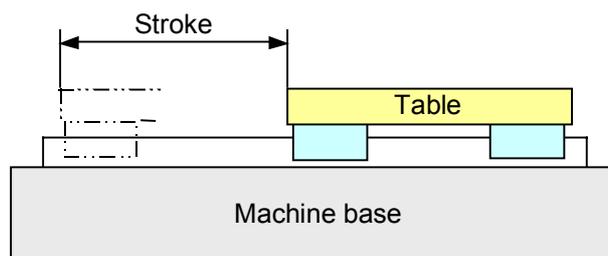
6. Accuracy

Based on the running accuracy of ball slides that travel on the rails, the required motion accuracy is expressed in a particular accuracy grade, like P5 or PN.

7. Required Life

Required life is expressed in a total travel distance.
(For example, 5 000km)

Section 3 | A Selection Exercise

1 Use conditions

- Application : Transport system
- Work weight : W1＝6000 N (Loaded on the center of table)
- Table weight : W2＝2000 N
- Speed : 30 m/min
- Stroke : 1500 mm
- Accuracy : Not particularly specified
  (Low accuracy acceptable.)
- Required life : Not particularly specified.
  However, a load capacity twice as much as that
  of the linear guides (rated basic dynamic load:
  6 000 N) that are equipped with an existing
  machine is preferred.
- Others: (1) Shorter delivery
  (2) It is hard to mount a linear guide accurately.
  (A higher self aligning function required.)
  (3) Machine height needs to be as low as possible.
  (4) The existing machine is driven by ball screw
  with 32 mm in diameter.
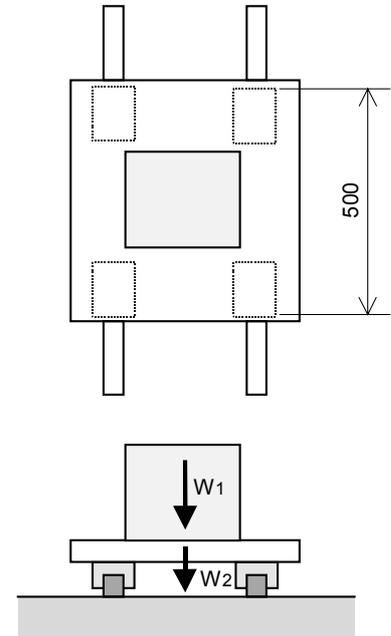
2 Selection steps

1) Refer to Lesson 1, Section 1 "Series of NSK Linear Guides" in view of transport system and mounting accuracy (capable of mounting error absorption).
Choose an LH or LS series that features a high load capacity in the vertical direction and self-alignment. Select from interchangeable parts that are available at standard stocks for quick delivery.
2) Select the size (type) No. 30 according to the diameter of ball screw shaft.
3) Refer to the Dimensions Table in the catalog for the type that satisfies desired rated basic dynamic load (12 000 N).
4) To meet the requirement for low machine height, choose LAS30CL or LAS30KL for its low assembled height and compactness.
5) Total rail length is calculated to 2 040 mm by adding up the stroke (1 500), the ball slide assembling span (500), and a little extra for margin. The rail number L1S302040 (Z) is applicable from the "Table of LS Series Rail Dimensions" in the catalog. Make sure that the length can be covered by one rail so that a butting rail won't be necessary.
6) Section 2 of Lesson 1 tells this is an interchangeable part and has an accuracy grade of "Normal Grade (PC)." This choice is acceptable since the accuracy is not required.
7) Section 2 of Lesson 1 also tells the preload type for "Normal Grade (PC)" is "Fine Clearance." There is no need to select "Fine Preload" for the transport system.
8) Based on the choice of "Fine Clearance," select rail reference number of L1S302040.

3 Checking for basic safety

(1) Allowable speed

From viewpoint of the durability of a part for ball-recirculation (end cap), there is a certain limit with the maximum speed. If the speed exceeds the limit, the end caps would be damaged. Thereby, the steel balls would not be able to circulate any longer, and eventually the ball slide locks up, or the balls would fall apart and throw out. Thus, the ball slides would finally lose their functions.

Allowable speed of all standard model: 100 m/min

As to the case of our selection exercise, the required speed is 30 m/min, which is far less than the criterion above. (So, it should be no problem.)

[Note] : Further higher speed is available when the end caps for high-speed specification are furnished.
Please contact the Engineering Department if the maximum speed exceeds 100 m/min.

(2) Life expectancy

Since there is no specific requirement, we skip this particular subject this time.

Based upon the above study, we are going to propose the following to the user.
- **Ball slide : LAS30CL or LAS30KL (four pieces)**
- **Rails   : LIS302040 (two pieces)**
- **Delivery   : Immediate delivery possible since we have the items in stocked**

Lesson 3: Outlines of Series for Special Application

Every customer has different needs. We have to have enough knowledge on the whole picture of NSK linear guides in order to deal with such needs. This section introduces the summary of the linear guides for special application.

| Section 1 | Temperature Resistant Series |

◆ **The linear guides of this series are constructed of stainless steel ball re-circulation parts and equipped with fluorinated rubber seals.**

<<Main Features>>

1) Maximum service temperature of 150°C (200°C for instantaneous time durations)
2) Highly anticorrosive (In case of stainless steel rails and ball slides are used.)

<<Applicable models>>

Series	Model number	
	High temperature resistant specification	High antirust specification
LH	20,25,30,35,45,55	20,25,30
LS	15,20,25,30	15,20,25,30
LW	17,21,27	
LU	09,12,15 (AL or TL type)	09,12,15
LE	12,15 (AR or TR type)	09,12,15 (AR or TR type)

<<Example of application>>

Welding machines, glasswork equipment, equipment for heat treatment equipment, semiconductor manufacturing equipment such as diffusion furnaces, and the like.

<<Note of selection>>

● Rust preventive property is not necessarily perfect since the rails and ball slides are made of martensitic stainless steel.

Section 2 | **S1 Series**

◆ **This series has been developed for application that requires a low noise for better working environment and highly smooth operation for high performance.**

<<Structure>>

In order to prevent direct ball to ball contact and/or jamming of balls, retainer pieces made of plastic material are inserted between balls.

<<Main features>>
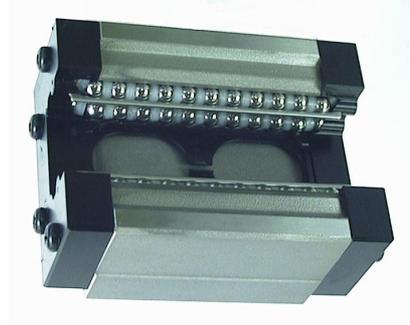
1) Low noise, soft noise tone (not harsh to the ears), and low vibration.
2) Smooth operation.
3) High load capacity. [See note]
4) Interchangeable with conventional ball slides in terms of dimensions.
5) Accuracy grade: P3 – PN (five accuracy grades available)
6) Applicable level of preloads: Z3, Z1 and Z0.

[Note]: Optimized design of the retainer piece has enabled to minimize in decreasing the number of steel balls, which sustain a load, and thus, reducing in the load capacity of a linear guide has kept to a minimum.

<<Application examples>>

Measuring/inspecting apparatuses, medical equipment, scanners, pattern generator, steppers, electric wire discharge machines, etc.

<<Notes for selection>>

● The operational temperature range is limited to 50 °C in maximum for regular use, and 80 °C for an instantaneous duration.

● Rails and ball slides are not interchangeable (random matching).

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Section 3 | MF Series

◆ **These are the linear guides furnished with the "NSK K1™" lubrication units.**

<<Main features>>

1) Maintenance-free for a prolonged time.
2) Work environment will not be contaminated by lubrication oil. (A clean environment will be maintained.)
3) Withstands environment where water washes away lubricant oil. (Longer life in a hostile environment.)
4) Functions of linear guides are maintained even in environment where oil-absorbing dusts exist. (Longer life in adverse environment).
5) Interchangeable ball slides are regularly stored as the standard stock items (Short in delivery lead time).
6) Accuracy grade and preload specifications are the same as those of existing ones.

<<Application examples>>

Machine tools, semiconductors/liquid crystal display manufacturing equipment, food/medical apparatus, automotive manufacturing systems, woodworking machine, paper production/textiles machine, robots, etc.

<<Notes for selection>>

● Since the installation of "NSK K1™" lubrication unit makes the overall length of ball slide slightly longer, take due cares on relevant dimensions when replacing existing components.

● The attachment of "NSK K1™" lubrication unit also makes dynamic friction force slightly larger.

● Maximum service temperature is 50 °C in normal use or 80 °C for an instantaneous duration.

● Degreasing organic solvents such as hexane and paint thinners, kerosene or rust preventive oils containing kerosene are not allowed for use with "NSK K1™" lubrication unit.

Supplement: Comparison between NSK and Competitors.

This section provides various comparison tables with the competitors so that you can easily select (or translate to) the product numbers of NSK linear guides when a customer asked to quote for a competitor's product numbers.

Section 1 | Reference Number and Specification Number

1 NSK

◆ **Reference number of preloaded assembly**

| LH | 30 | 1000 | AN | C | 2 | ** | P6 | 1 |

(1) Series

(2) Size number

(3) Rail length (mm)

(4) Ball slide shape code (shape, height)

(5) Material/surface treatment
(C: NSK standard; K: Stainless steel; etc)

(6) Number of ball slide/rail

(9) Preload code

    0: Fine clearance   (Z0)
    1: Slight preload   (Z1)
    2: Light preload   (Z2)
    3: Medium preload (Z3)
    4: Heavy preload   (Z4)

(8) Accuracy grade

(7) Design serial number

◆ **Reference number of interchangeable type**

1) Rail

| L | 1 | H | 30 | 1000 | S | Z |

(1) Series
(10) Interchangeable rail
(2) Size number
(3) Rail length (mm)
(5) Material code (S: stainless steel; No code: standard)
(9) Preload code (Z: slight preload; No code: fine)

2) Ball slide

| L | A | H | 30 | AN | S | Z |

(1) Series
(10) Interchangeable ball slide
(2) Size number (nominal)
(4) Ball slide shape code (shape and height)
(5) Material code (S: stainless steel; No code: standard)
(9) Preload code (Z: slight preload; No code: fine clearance)

3) Reference number of assembled interchangeable type

| LH | 30 | 1000 | AN | C | 2 | – | ** | PC | Z |

(1) Series
(2) Size number
(3) Rail length (mm)
(4) Ball slide shape code (shape, height)
(5) Material/surface treatment
   (C: NSK standard; K: Stainless steel; etc)
(6) Number of ball slide/rail
(7) Design serial number
(8) Accuracy grade (PC: Notmal)
(9) Preload code
   T: Fine clearance (ZT)
   Z: Slight preload   (Z1)
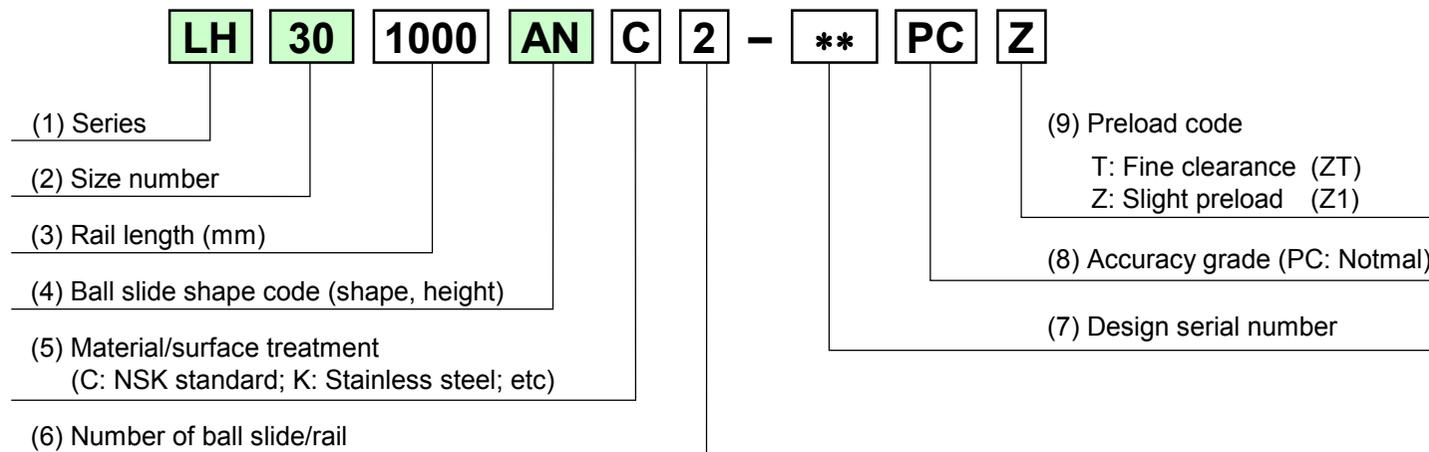
2 THK

◆ **Reference number of standard size**

HSR30 **R** **2** **SS** **C1** **M** **+** **1000L** **H** **M** **−** **II**

(1) (2) Model No. (series, size)

(4) Ball slide shape code (shape and height)

(6) Number of ball slide/rail

(11) Seal code (SS: End + bottom seals; UU: End seals only)

(9) Preload code　　No code: Fine clearance/slight preload
　　　　　　　　　　C1: Light preload;　C0: Medium preload

(5) Material code (Ball slide)　　M: Stainless steel
　　　　　　　　　　　　　　　　No code: standard material

(12) Number of rail/set
　　　No code : One rail
　　　　　　II : 2 rails
　　　　　III : 3 rails
　　　　　IV : 4 rails

(5) Material code (rail)
　　　M: stainless steel
　　　No code: standard

(8) Accuracy grade

(3) Rail length (mm)

◆ **Reference number for miniature size**

2 **RSR15V** **M** **UU** **C1** **+** **230L** **H** **M** **−** **II**

(6) Number of ball slide/rail

(1) (2) Model No. (series, size)

(5) Material code (Ball slide)
　　(M: stainless steel; No code: standard)

(11) Seal code (UU: end seals)

(9) Preload code　　No code : Fine clearance ~ slight preload
　　　　　　　　　　C1　　: Light preload

(12) Number of rail/set
　　　No code : One rail
　　　　　　II : 2 rails
　　　　　III : 3 rails
　　　　　IV : 4 rails

(5) Material code (rail)
　　　M: stainless steel
　　　No code: standard

(8) Accuracy grade

(3) Rail length (mm)

Note: "(12) Number of rails" means the quantity of rails used for single driving axis.

3 IKO

◆ Reference number of assembled unit

| LWHD | 30 | C2 | R1000 | B | SL | T₁ | H | S1 | /F |

(1) Series (model)

(2) Size

(6) Number of ball slide/rail

(3) Rail length (mm)

(5) Material code (SL: stainless steel; no code: standard) [Note]

(9) Preload code

T_C : Clearance
T_0 : Fine clearance
No code : Slight preload
T_1 : Slight preload
T_2 : Medium preload
T_3 : Heavy preload

(14) Supplementary code

/F : Cap to cover bolt holes
/L : Low temperature chrome plating
/W2 : Two rails/set
No code : Standard

(13) Interchangeability code

No code : Non-interchangeable
S1 : S1 specification
S2 : S2 specification

(8) Accuracy grade

[Note]: In case of the miniature series, CS is for standard and no code is for stainless steel.

◆ Reference number of interchangeable series

1) Rail

LWHD	30	R1000	B	SL	H	S1	/F

(1) Series (model)

(2) Size

(3) Rail length (mm) [Note]

(5) Material code (SL: stainless steel; No code: standard)

(8) Accuracy grade

(13) Interchangeability code — S1: S1 specification / S2: S2 specification

(14) Supplementary code —
F : Low temperature chrome plating
/L : Cap to cover bolt hole
No code : standard

2) Ball slide

LWHD	30	C1	B	SL	T1	H	S1	/L

(1) Series (model)

(2) Size

(6) C1 code only for number [Note]

(5) Material code (SL: stainless steel; No code: standard)

(9) Preload code —
No code: slight preload
T_1: slight preload

(8) Accuracy grade

(13) Interchangeability code — S1: S1 specification / S2: S2 specification

(14) Supplementary code —
/L: Low temperature chrome plating
No code: standard

[Note]: In case of miniature series, CS is for standard and no code for stainless steel.

4 HIWIN

◆ **Reference number of non-interchangeable series**

LGH30 **CA** **E** **2** **R** **1000** **E** **Z1** **H** **II** **+** **ZZ**

(1) (2) Model number
(series, size)

(4) Ball slide shape
(shape and height)

(15) Special treatment for ball slide
(E: some; No code: none)

(6) Number of ball slide/rail

(16) Bolt hole to fix rail
(R: through hole; T: tapped hole)

(3) Rail length (mm)

(17) Special treatment for rail (E: some; No code: none)

(11) Seal code
(No code: standard)
(ZZ, DD, KK, HH, U)

No code : 1 rail
II : 2 rails
III : 3 rails
(12) Number of rail/set   IV : 4 rails

(8) Accuracy grade

ZF : Fine clearance
Z0 : No preload
Z1 : Slight preload
Z2 : Medium preload
Z3 : Heavy preload
(9) Preload code   Z4 : Ultra heavy preload

◆ **Reference number of interchangeable series**

1) Rail

LG **R** **30** **R** **1000** **E** **H** **M**

(1) Series (model)

(18) Rail

(2) Size

(16) Bolt hole to fix rail   R: through hole   T: tapped hole

(3) Rail length (mm)

(5) Material code
   M   : stainless steel
   No code : standard

(8) Accuracy grade

(17) Special treatment for rail
   (E: some; No code: none)

2) Ball slide

LGH30 **CA** **E** **Z1** **H** **+** **ZZ**

(1) (2) Model No. (series, size)

(4) Shape code (shape, height)

(15) Special treatment for ball slide   E: some   No code: none

(9) Preload code   ZF : fine clearance   Z0 : No preload   Z1 : slight preload

(11) Seal code
   (No code: standard)
   (ZZ, DD, KK, HH, U)

(8) Accuracy grade (C, H, P)

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Section 2 | Comparison of Accuracy Grade and Preload Code

◆ **Accuracy grade**

Grade	NSK		THK	IKO		HIWIN		STAR
	Preloaded assembly	Interchangeable type		Non-interchangeable type	Interchangeable type	Non-interchangeable type	Interchangeable type	
Normal	PN	PC	No code	No code	(No code)	C	C	N
Precision	P6	–	H	H	H	H	H	H
High precision	P5	–	P	P	P	P	P	P
Super precision	P4	–	SP	SP	–	SP	–	SP
Ultra precision	P3	–	UP	UP	–	UP	–	UP

[Note] An accuracy grade that is put in the parentheses is applicable to limited series only.

◆ **Preload code**

Classification	NSK		THK	IKO		HIWIN		STAR
	Preloaded assembly	Interchangeable type		Preloaded assembly	Interchangeable type	Preloaded assembly	Interchangeable type	
Clearance	–	–	–	Tc	(Tc)	ZF	ZF	–
Fine clearance	Z0	ZT	No code	T0	–	Z0 (clearance 0)	Z0 (clearance 0)	✓
Slight preload	Z1	ZZ	C1	No code	No code	Z1	Z1	–
Light preload	Z2	–	C1	T1	(T1)	Z2	–	✓
Medium preload	Z3	–	C0	T2	–	Z3	–	✓
Heavy preload	Z4	–	C0	T3	–	Z4	–	✓

[Note1] An accuracy grade that is put in the parentheses is applicable to limited series only.
[Note2] No preload code is available at STAR. Checks (✓) on the table denote that preload is applicable for checked models.

Section 3 | Comparison of Model Number

When you make a comparison, refer to the notes on the last page of these comparison tables.

		NSK		THK		IKO		HIWIN (Taiwn)		STAR (Germany)	
		High load	Super high load	High load	Super high load	High load	Super high load	High load	Super high load	High load	Super high load
High load	Square type	☆LH15AN	☆LH15BN	HSR15R	*****	☆LWHD15••B	*****	☆LGH15CA	*	1621-1	*****
		☆LH20AN	☆LH20BN	HSR20R	HSR20LR	☆LWHS20••B	☆LWHSG20	☆LGH20CA	☆LGW20HA	1622-8	1623-8
		☆LH25AN	☆LH25BN	HSR25R	HSR25LR	☆LWHD25••B	☆LWHDG25	☆LGH25CA	☆LGW25HA	1621-2	1624-2
		☆LH30AN	☆LH30BN	HSR30R	HSR30LR	☆LWHD30••B	☆LWHDG30	☆LGH30CA	☆LGW30HA	1621-7	1624-7
		☆LH35AN	☆LH35BN	HSR35R	HSR35LR	☆LWHD35••B	☆LWHDG35	☆LGH35CA	☆LGW35HA	1621-3	1624-3
		☆LH45AN	☆LH45BN	HSR45R	HSR45LR	☆LWHD45••B	☆LWHDG45	☆LGH45CA	☆LGW45HA	1621-4	1624-4
		☆LH55AN	☆LH55BN	HSR55R	HSR55LR	LWHD55••B	LWHDG55	☆LGH55CA	☆LGW55HA	1621-5	1624-5
		☆LH65AN	☆LH65BN	HSR65R	HSR65LR	LWHD65••B	LWHDG65	☆LGH65CA	☆LGW65HA	1622-6	1623-6
	Flanged type	☆LH15EL	☆LH15GL	HSR15A	*****	☆LWHT15••B	*****	☆LGW15CA	*****	1651-1	1653-1
		☆LH20EL	☆LH20GL	HSR20A	HSR20LA	☆LWHT20••B	☆LWHTG20	☆LGW20CA	☆LGW20HA	1651-8	1653-8
		☆LH25EL	☆LH25GL	HSR25A	HSR25LA	☆LWHT25••B	☆LWHTG25	☆LGW25CA	☆LGW25HA	1651-2	1653-2
		☆LH30EL	☆LH30GL	HSR30A	HSR30LA	☆LWHT30••B	☆LWHTG30	☆LGW30CA	☆LGW30HA	1651-7	1653-7
		☆LH35EL	☆LH35GL	HSR35A	HSR35LA	☆LWHT35••B	☆LWHTG35	☆LGW35CA	☆LGW35HA	1651-3	1653-3
		☆LH45EL	☆LH45GL	HSR45A	HSR45LA	☆LWHT45••B	☆LWHTG45	☆LGW45CA	☆LGW45HA	1651-4	1653-4
		☆LH55EL	☆LH55GL	HSR55A	HSR55LA	LWHT55••B	LWHTG55	☆LGW55CA	☆LGW55HA	1651-5	1653-5
		☆LH65EL	☆LH65GL	HSR65A	HSR65LA	LWHT65••B	LWHTG65	☆LGW65CA	☆LGW65HA	1651-6	1653-6
		–	LH85GL	–	HSR85LA	–	*****	–	*****	–	*****
		☆LH15FL	☆LH15HL	HSR15B	*****	☆LWH15••B	*****	☆LGW15CB	*****	*1651-1	*1653-1
		☆LH20FL	☆LH20HL	HSR20B	HSR20LB	☆LWH20••B	☆LWHG20	☆LGW20CB	☆LGW20HB	*1651-8	*1653-8
		☆LH25FL	☆LH25HL	HSR25B	HSR25LB	☆LWH25••B	☆LWHG25	☆LGW25CB	☆LGW25HB	*1651-2	*1653-2
		☆LH30FL	☆LH30HL	HSR30B	HSR30LB	☆LWH30••B	☆LWHG30	☆LGW30CB	☆LGW30HB	*1651-7	*1653-7
		☆LH35FL	☆LH35HL	HSR35B	HSR35LB	☆LWH35••B	☆LWEHG35	☆LGW35CB	☆LGW35HB	*1651-3	*1653-3
		☆LH45FL	☆LH45HL	HSR45B	HSR45LB	☆LWH45••B	☆LWHG45	☆LGW45CB	☆LGW45HB	*1651-4	*1653-4
		☆LH55FL	☆LH55HL	HSR55B	HSR55LB	LWH55••B	LWEHG55	☆LGW55CB	☆LGW55hB	*1651-5	*1653-5
		☆LH65FL	☆LH65HL	HSR65B	HSR65LB	LWH65••B	LWHG65	☆LGW65CB	☆LGW65HB	*1651-6	*1653-6
		–	LH85HL	–	HSR85LB	–	*****	–	*****	–	*****

		NSK		THK		IKO		HIWIN (Taiwn)		STAR (Germany)	
		High load	Medium load	High load	Medium load	High load	Medium load	High load	Medium load	High load	Medium load
Compact (low profile) type	Square	☆LS15AL	☆LS15CL	SR15W	SR15V	☆LWES15	☆LWESC15	☆AGH15CA	☆AGH15SA	1622-1	1666-1
		☆LS20AL	☆LS20CL	SR20W	SR20V	☆LWES20	☆LWESC20	☆AGH20CA	☆AGH20SA	1694-8	1664-8
		☆LS25AL	☆LS25CL	SR25WY	SR25VY	☆LWES25	☆LWESC25	☆AGH25CA	☆AGH25SA	1694-2	1664-2
		☆LS30AL	☆LS30CL	SR30W	SR30V	☆LWES30	☆LWESC30	☆AGH30CA	☆AGH30SA	*****	*****
		☆LS35AL	☆LS35CL	SR35W	SR35V	☆LWES35	☆LWESC35	☆AGH35CA	☆AGH35SA	1622-3	1666-3
	Flanged type	☆LS15EL	LS15JL	*****	*****	☆LWET15	☆LWETC15	☆AGW15CA	☆AGW15SA	*****	*****
		☆LS20EL	LS20JL	*****	*****	☆LWET20	☆LWETC20	☆AGW20CA	☆AGW20SA	1693-8	1663-8
		☆LS25EL	LS25JL	*****	*****	☆LWET25	☆LWETC25	☆AGW25CA	☆AGW25SA	1693-2	1663-2
		☆LS30EL	LS30JL	*****	*****	☆LWET30	☆LWETC30	☆AGW30CA	☆AGW30SA	*****	*****
		☆LS35EL	LS35JL	*****	*****	☆LWET35	☆LWETC35	☆AGW35CA	☆AGW35SA	*****	1665-3
		☆LS15FL	☆LS15KL	SR15TB	SR15SB	☆LWE15	☆LWEC15	☆AGW15CB	☆AGW15SB	*****	*****
		☆LS20FL	☆LS20KL	SR20TB	SR20SB	☆LWE20	☆LWEC20	☆AGW20CB	☆AGW20SB	1693-8	1663-8
		☆LS25FL	☆LS25KL	SR25TBY	SR25SBY	☆LWE25	☆LWEC25	☆AGW25CB	☆AGW25SB	1693-2	1663-2
		☆LS30FL	☆LS30KL	SR30TB	SR30SB	☆LWE30	☆LWEC30	☆AGW30CB	☆AGW30SB	*****	*****
		☆LS35FL	☆LS35KL	SR35TB	SR35SB	☆LWE35	☆LWEC35	☆AGW35CB	☆AGW35SB	*****	1665-3
		High load	Super high load	High load	Super high load	High load	Super high load	High load	Super high load	High load	Super high load
Super rigid type	Square low	LA35AL	LA35BL	*****	*****	*****	*****	*****	*****	*****	*****
		LA45AL	LA45BL	*****	*****	*****	*****	*****	*****	*****	*****
		LA55AL	LA55BL	*****	*****	*****	*****	*****	*****	*****	*****
	Square type	LA25AN	LA25BN	*****	*****	LRXD25	LRXDG25	*****	*****	1821-2	1824-2
		LA30AN	LA30BN	*****	*****	LRXD30	LRXDG30	*****	*****	*****	*****
		LA35AN	LA35BN	*****	SRG35LR	LRXD35	LRXDG35	*****	*****	1821-3	1824-3
		LA45AN	LA45BN	*****	SRG45LR	LRXD45	LRXDG45	*****	*****	1821-4	1824-4
		LA55AN	LA55BN	*****	SRG55LR	LRXD55	LRXDG55	*****	*****	1821-5	1824-5
		LA65AN	LA65BN	*****	SRG65LV	LRXD65	LRXDG65	*****	*****	*****	1824-6
	Flanged type	LA25EL	LA25GL	*****	*****	LRX25	LRXG25	*****	*****	1851-2	1853-2
		LA30EL	LA30GL	*****	*****	LRX30	LRXG30	*****	*****	*****	*****
		LA35EL	LA35GL	*****	SRG35LC	LRX35	LRXG35	*****	*****	1851-3	1853-3
		LA45EL	LA45GL	*****	SRG45LC	LRX45	LRXG45	*****	*****	1851-4	1853-4
		LA55EL	LA55GL	*****	SRG55LC	LRX55	LRXG55	*****	*****	1851-5	1853-5
		LA65EL	LA65GL	*****	SRG65LC	LRX65	LRXG65	*****	*****	*****	1853-6
		LA25FL	LA25HL	*****	*****	LRX25	LRXG25	*****	*****	*1851-2	*1853-2
		LA30FL	LA30HL	*****	*****	*LRX30	*LRXG30	*****	*****	*****	*****
		LA35FL	LA35HL	*****	*****	*LRX35	*LRXG35	*****	*****	*1851-3	*1853-3
		LA45FL	LA45HL	*****	*****	*LRX45	*LRXG45	*****	*****	*1851-4	*1853-4
		LA55FL	LA55HL	*****	*****	*LRX55	*LRXG55	*****	*****	*1851-5	*1853-5
		LA65FL	LA65HL	*****	*****	*LRX65	*LRXG65	*****	*****	*****	*1853-6

		NSK		THK		IKO		HIWIN (Taiwn)		STAR (Germany)	
		High load	Super load	High load	Super load	High load	Super load	High load	Super load	High load	Super load
High rigid type	Square low	LY15AL	–	*****	–	LWHS15••B	–	*****	–	1622-1	–
		LY20AL	LY20BL	HSR20R	HSR20LR	LWHS20••B	LWHSG20	*****	*****	1622-8	1623-8
		LY25AL	LY25BL	*****	*****	LWHS25••B	LWHSG25	*****	*****	1622-2	1623-2
		LY30AL	LY30BL	*****	*****	LWHS30••B	LWHSG30	*****	*****	1622-7	1623-7
		LY35AL	LY35BL	*****	*****	*****	*****	*****	*****	1622-3	1623-3
		LY45AL	LY45BL	*****	*****	*****	*****	*****	*****	1622-4	1623-4
		LY55AL	LY55BL	*****	*****	*****	*****	*****	*****	1622-5	1623-5
	Square type	LY15AN	–	HSR15R	–	LWHD15••B	–	LGH15CA	–	1621-1	–
		LY25AN	LY25BN	HSR25R	HSR25LR	LWHD25••B	LWHGD25	LGH25CA	LGH25HA	1621-2	1624-2
		LY30AN	LY30BN	HSR30R	HSR30LR	LWHD30••B	LWHGD30	LGH30CA	LGH30HA	1621-7	1624-7
		LY35AN	LY35BN	HSR35R	HSR35LR	LWHD35••B	LWHGD35	LGH35CA	LGH35HA	1621-3	1624-3
		LY45AN	LY45BN	HSR45R	HSR45LR	LWHD45••B	LWHGD45	LGH45CA	LGH45HA	1621-4	1624-4
		LY55AN	LY55BN	HSR55R	HSR55LR	LWHD55••B	LWHGD55	LGH55CA	LGH55HA	1621-5	1624-5
		LY65AN	LY65BN	HSR65R	HSR65LR	LWHD65••B	LWHGD65	LGH65CA	LGH65HA	1622-6	1624-6
	Flanged type	LY15EL	–	HSR15A	–	LWHT15••B	–	LGW15CA	–	1651-1	–
		LY20EL	LY20GL	HSR20A	HSR20LA	LWHT20••B	LWHTG20	LGW20CA	LGW20HA	1651-8	1653-8
		LY25EL	LY25GL	HSR25A	HSR25LA	LWHT25••B	LWHTG25	LGW25CA	LGW25HA	1651-2	1653-2
		LY30EL	LY30GL	HSR30A	HSR30LA	LWHT30••B	LWHTG30	LGW30CA	LGW30HA	1651-7	1653-7
		LY30EL	–	*****	–	*****	–	*****	–	*****	–
		LY35EL	LY35GL	HSR35A	HSR35LA	LWHT35••B	LWHTG35	LGW35CA	LGW35HA	1651-3	1653-3
		LY45EL	LY45GL	HSR45A	HSR45LA	LWHT45••B	LWHTG45	LGW45CA	LGW45HA	1651-4	1653-4
		LY55EL	LY55GL	HSR55A	HSR55LA	LWHT55••B	LWHTG55	LGW55CA	LGW55HA	1651-5	1653-5
		LY65EL	LY65GL	HSR65A	HSR65LA	LWHT65••B	LWHTG65	LGW65C0A	LGW65HA	1651-6	1653-6
		LY15FL	–	HSR15B	–	LWH15••B	–	LGW15CB	–	*1651-1	–
		LY20FL	LY20HL	HSR20B	HSR20LB	LWH20••B	LWHG20	LGW20CB	LGW20HB	*1651-8	*1653-8
		LY25FL	LY25HL	HSR25B	HSR25LB	LWH25••B	LWHG25	LGW25CB	LGW25HB	*1651-2	*1653-2
		LY30FL	LY30HL	HSR30B	HSR30LB	LWH30••B	LWHG30	LGW30CB	LGW30HB	*1651-7	*1653-7
		LY35FL	LY35HL	HSR35B	HSR35LB	LWH35••B	LWHG35	LGW35CB	LGW35HB	*1651-3	*1653-3
		LY45FL	LY45HL	HSR45B	HSR45LB	LWH45••B	LWHG45	LGW45CB	LGW45HB	*1651-4	*1653-4
		LY55FL	LY55HL	HSR55B	HSR55LB	LWH55••B	LWHG55	LGW55CB	LGW55HB	*1651-5	*1653-5
		LY65FL	LY65HL	HSR65B	HSR65LB	LWH65••B	LWHG65	LGW65CB	LGW60HB	*1651-6	*1653-6
Wide rail	Flanged	☆LW17EL		HRW17CA		LWFF33		*****		*****	
		☆LW21EL		HRW21CA		LWFF37		*****		*****	
		☆LW27EL		HRW27CA		LWFF42		*****		1671-8	
		☆LW35EL		HRW35CA		*****		*****		1671-2	
		☆LW50EL		HRW50CA		*****		*****		1671-3	

		NSK		THK		IKO		HIWIN (Taiwn)		STAR (Germany)	
		Medium load	High load	Medium load	High load	Medium load	High load	Medium load	High load	Medium load	High load
Miniature type	Compact type	LU05TL	–	RSR5M	–	LWL5••B	–	*****	–	*****	–
		LU07AL	–	RSR7M	–	☆LWL7••B	–	MGN7C	–	0442-7	–
		LU09AL	LU09BL	*****	*****	LWL9	*****	*****	*****	*****	*****
		LU09TL	LU09UL	RSR9KM	RSR9N	LWL9••B	*****	MGN9C	MGN9H	*****	*****
		☆LU09AR	–	*****	–	*****	–	*****	–	0442-9	–
		☆LU09TR	–	RSH9KM	–	☆LWL9••B	–	*****	–	0442-8	–
		LU12AL	LU12BL	*****	*****	*****	*****	*****	*****	*****	*****
		AU12TL	LU12UL	RSR12VM	RSR12N	☆LWL12••B	☆LWLG12••B	MGN12C	MGN12H	*****	*****
		☆LU12AR	–	*****	–	*****	–	*****	–	*****	–
		☆LU12TR	–	RSR12VM	–	☆LWL12••B	–	*****	–	0442-2	–
		☆LU15AL	LU15BL	RSR15VM	RSR15N	☆LWL15••B	☆LWLG15••B	MGN15C	MGN15H	0442-5	*****
	Wide rail type	LE05AL	–	*****	–	LWLF10••B	–	*****	–	*****	–
		LE07TL	LE07UL	*****	*****	☆LWLF14••B	☆LWLFG14••B	MGW7C	MGW7H	*****	*****
		LE09AL	LE09BL	RSR9WVM	*****	LWLF18	*****	*****	*****	*****	*****
		LE09TL	LE09UL	*****	RSR12WN	☆LWLF18••B	☆LWLFG18••B	MGW9C	MGW9H	*****	*****
		☆LE09AR	–	*****	–	*****	–	*****	–	*****	–
		☆LE09TR	–	RSH9WZM	–	☆LWLF18••B	–	MGW9C	–	0443-8	–
		LE12AL	LE12BL	RSR12WVM	RSR12WN	LWLF24	☆LWLFG24••B	MGW12C	MGW12H	*****	*****
		☆LE12AR	–	RSH12WZM	–	☆LWLF24••B	–	MGW12C	–	0443-2	–
		LE15AL	LE15BL	RSH15WZM	RSR15WN	LWLF42	☆LWLFG42••B	MGW15C	MGW15H	*****	*****
		☆LE15AR	–	RSH15WZM	–	☆LWLF42••B	–	MGW15C	–	0443-5	–
		Light load type		Light load type		Light load type		Light load type		Light load type	
		LE05CL		*****		LWLF10••B		*****		*****	
		LE07SL		*****		☆LWLF14••B		*****		*****	
		LE09CL		*****		*****		*****		*****	
		LE09SL		*****		☆LWLF18••B		*****		*****	
		LE12CL		*****		☆LWLF24••B		*****		*****	
		LE15CL		*****		☆LWLF42••B		*****		*****	

		NSK		THK		IKO		HIWIN (Taiwn)		STAR (Germany)	
		High load	Super load	High load	Super load	High load	Super load	High load	Super load	High load	Super load
Low noise/Smooth operation type	Square type	SH20AN	SH20BN	SHS20V	SHS20LV	*****	*****	*****	*****	1622-8	*****
		SH25AN	SH25BN	SHS25R	SHS25LR	*****	*****	*****	*****	*****	*****
		SH30AN	SH30BN	SHS30R	SHS30LR	*****	*****	*****	*****	*****	*****
	Flanged type	SH20EL	SH20GL	SHS20C	SHS20LC	*****	*****	*****	*****	1651-8	*****
		SH25EL	SH25GL	SHS25C	SHS25LC	*****	*****	*****	*****	1651-2	*****
		SH30EL	SH30GL	SHS30C	SHS30LC	*****	*****	*****	*****	1651-7	*****
		SH20FL	SH20HL	SHS20C	SHS20LC	*****	*****	*****	*****	1651-8	*****
		SH25FL	SH25HL	SHS25C	SHS25LC	*****	*****	*****	*****	1651-2	*****
		SH30FL	SH30HL	SHS30C	SHS30LC	*****	*****	*****	*****	1651-7	*****
		High load	Medium load	High load	Medium load	High load	Medium load	High load	Medium load	High load	Medium load
	Square type	SS15AL	SS15CL	SSR15XWY	SSR15XVY	LWES15••Q	*****	*****	*****	1622-1	*****
		SS20AL	SS20CL	SSR20XW	XXR20XV	LWES20••Q	*****	*****	*****	*****	*****
		SS25AL	SS25CL	SSR25XWY	SSR25XVY	LWES25••Q	*****	*****	*****	*****	*****
		SS30AL	SS30CL	SSR30XW	*****	LWES30••Q	*****	*****	*****	*****	*****
	Flange type	SS15EL	SS15JL	*****	*****	LWET15••Q	*****	*****	*****	*****	*****
		SS20EL	SS20JL	*****	*****	LWET20••Q	*****	*****	*****	*****	*****
		SS25EL	SS25JL	*****	*****	LWET25••Q	*****	*****	*****	*****	*****
		SS30EL	SS30JL	*****	*****	LWET30••Q	*****	*****	*****	*****	*****
		SS15FL	SS15KL	SSR15XTBY	*****	LWE15••Q	*****	*****	*****	*****	*****
		SS20FL	SS20KL	SSR20XTB	*****	LWE20••Q	*****	*****	*****	*****	*****
		SS25FL	SS25KL	SSR25XTBY	*****	LWE25••Q	*****	*****	*****	*****	*****
		SS30FL	SS30KL	*****	*****	LWE30••Q	*****	*****	*****	*****	*****

[Notes]
1) Model number marked with ☆ is available in either preloaded assembly or interchangeable type.
2) Comparisons in above tables are made on installation compatibility. Load carrying capacity and external dimensions are not necessarily the same.
3) Model that has difference, even by 1 mm, in dimensions related to installation, such as height or size and position of tap hole, is excluded from the list. However, we dare to list models marked with an asterisk (∗), whose tap hole of ball slide doubles as a tap hole and a drilled hole, even though their interchangeability in bolt size with NSK-FL/HL models is not necessarily perfect.
4) NSK LA Series is compared with roller guide way bearings of competitors for their interchangeability in dimensions related to installation.
5) EL/GL model of flange type have tapped hole for installation, while FL/HL models have drilled hole.

NSK

Chapter 4
Selection of Linear Guides
(Intermediate Course)

NSK Ltd.

Precision Machinery & Parts
e-Project Team

Lesson 1: Preparation for Linear Guide Selection

This section provides the minimum requirements for selecting a linear guide. In order for you to correctly follow the user's needs and convey such information appropriately to the Engineering Department for their assistance as occasion demands, please understand the following thoroughly.

Section 1 | Application Examples of Accuracy Grades and Preloads

The table below shows various application examples of the accuracy grade and the preload code for specific purpose. Use them as a reference whenever you select linear guides.

Classification	Application	Accuracy grade					Preload				
		Ultra precision P3	Super precision P4	High precision P5	Precision P6	Normal PN, PC	Heavy preload Z4	Medium preload Z3	Light preload Z2	Slight preload Z1, ZZ	Fine clearance Z0, ZT
Machine tools	Machining center		✓	✓	✓		✓	✓			
	Grinding machine	✓	✓	✓			✓	✓	✓		
	Lathe		✓	✓	✓		✓	✓			
	Milling machine		✓	✓	✓		✓	✓			
	Drilling machine			✓	✓		✓	✓			
	Boring machine		✓	✓	✓		✓	✓			
	Gear cutting machine		✓	✓	✓		✓	✓	✓		
	Die sinking machine		✓	✓	✓			✓	✓	✓	
	Laser beam machine		✓	✓	✓			✓	✓	✓	
	Electric discharge machine	✓	✓	✓			✓	✓			
Industrial machines and equipment	Punching press			✓	✓			✓	✓	✓	
	Stamping machine				✓	✓				✓	✓
	Welding machine				✓	✓		✓	✓	✓	✓
	Painting machine				✓	✓				✓	✓
	Textile machine				✓	✓				✓	✓
	Coil winder				✓	✓		✓	✓	✓	
	Woodworking machine			✓	✓	✓		✓	✓	✓	
	Glasswork machine				✓	✓				✓	✓
	Stone working machine				✓	✓				✓	✓
	Tire forming machine					✓				✓	✓
	ATC				✓	✓				✓	✓
	Industrial robot			✓	✓	✓		✓	✓	✓	✓
	Transport machine				✓	✓				✓	✓
	Packaging machine				✓	✓				✓	✓
	Construction machine					✓					✓
Semiconductor processing	Wafer prober	✓						✓		✓	
	Wire bonding machine		✓	✓				✓	✓	✓	
	PCB drilling machine			✓	✓			✓	✓	✓	
	Wafer slicing machine	✓	✓						✓		
	Wafer dicing machine	✓	✓						✓		
	Chip mounter			✓	✓			✓	✓	✓	
	IC handler			✓	✓					✓	
	Scanning machine			✓	✓					✓	
	Lithographic machine	✓	✓					✓	✓	✓	
Others	Measuring/inspection apparatus	✓	✓	✓	✓					✓	
	3D measuring equipment	✓	✓	✓	✓			✓	✓	✓	
	Medical apparatus		✓	✓	✓					✓	✓
	OA equipment				✓	✓				✓	✓
	Railway cars					✓				✓	✓
	Stage systems					✓					✓
	Pneumatic equipment				✓	✓				✓	✓

Section 2	Criteria for Selecting Preload Level and Verification of Preload Amount

1 Criterion for selecting preload code

Preload level	Use condition	Application example
Fine clearance Z0, ZT	• Where two linear guides (four ball slides/two rails) are used in parallel to each other with a fixed direction of load, and subject to low vibration and impact. • Where accuracy is not necessarily precise, but minimized sliding resistance is required.	Transportation equipment, office automation equipment glasswork machine welding machine, etc
Slight/light preload	• Where subject to a moment load • Where subject to a light load, and requiring high positioning accuracy.	Inspection/measuring device, medical equipment, lithography machine, chip mounter, wire bonding machine, laser beam machine, robot, woodworking machine, etc.
Medium/heavy preload	• Where very high rigidity is required. • Where subject to vibration or impact.	Machining center, lathe, gear cutting machine, grinding machine, etc.

2 How to verify amount of preload

● Amount of preload is evaluated and verified with preload dynamic friction force.

● The preload dynamic friction force is measured and controlled using an NSK dynamic friction force measuring equipment.

● The preload dynamic friction force is prescribed to the NSK engineering standard based on preload level and the model number of linear guides, and is controlled accordingly.

<<Terminology>>

Preload dynamic friction force: A force required to move a ball slide or a rail at a constant speed when a linear guide is preloaded as designated, and no external loads are applied.

♦ **Clipping data** ♦

(1) Why do we control the preload with dynamic frictional force?

As one of the purposes of the preload is for securing necessary rigidity, it is essential to measure the rigidity directly. However, measuring rigidity over the entire stroke is not really practical since it is both extremely difficult and time-consuming. Using its great store of measurement data on rigidity and preload dynamic friction forces, NSK has established a proprietary method to measure preloads via preload dynamic friction forces, which is now being applied to production at NSK.

(2) Relationship between preloaded force and rigidity of a linear guide:

Linear guide rigidity $\propto$ **(preload)$^{1/3}$** $\Rightarrow$ Rigidity increases only by 26% even the preload is doubled.

Section 3 | Limitation of Load

The linear guides have the limit of load they can bear. There are two kinds of load limit: One is a "static load limit" that deals with the safety limit of balls against their permanent deformation that occurs at contact points on the balls, and the other is associated with fatigue life caused by material deterioration of rolling surfaces of the balls.

1 Static load limit

- When subject to an excessive or large impact load, a local permanent deformation occurs between the rolling elements and the raceway surfaces. It requires to study on restricting such deformation within a certain limit. Permanent deformation causes noise or vibration, and will adversely affect the functions and life expectancy.

- Safety against permanent deformation is verified based upon both the basic static load rating and the basic static moment load rating.

- Allowable load (P_0) and allowable moment load (M_0) against permanent deformation are expressed as follows;
  (One half of the basic load rating is, approximately, the allowable load.)

$$P_0 = C_0/fs$$
$$M_0 = M_{R0}/fs , \qquad M_0 = M_{P0}/fs , \qquad M_0 = M_{Y0}/fs$$

Where;

◊ C_0 : Basic static load rating

◊ M_{R0} : Basic static moment load rating in rolling direction

◊ M_{P0} : Basic static moment load rating in pitching direction

◊ M_{Y0} : Basic static moment load rating in yawing direction

◊ fs : Allowable static load coefficient
  (a kind of safety factor)

  • For regular operation: $1 \sim 2$

  • When there are vibrations or shocks: $1.5 \sim 3$

* In case loads are applied in various directions in a composite manner, refer to the catalogues.

<<Static basic load rating, C_0>>
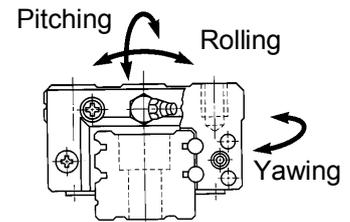
The basic static load rating C_0 is defined as a static load level that causes total permanent deformations formed in <u>a static state</u> on a ball and raceway surfaces at their contact points to be as large as 0.01% of the ball diameter. In the case of a linear guide, vertical load acting upon the center of the ball slide is employed. Such load is listed in the dimension tables in the catalogues. The permanent deformation is normally very minute. For example, for the ball diameter of 10mm, local deformation of 0.001mm is almost unnoticeable.

<<Basic static moment load rating (M_{R0}, M_{P0} and M_{Y0})>>

It is the moment load, under a static condition, at which the sum of a permanent deformation formed on a ball and that on ball grooves at their contact points is 0.01% of the ball diameter. Such values are listed in the dimension tables in the catalogues.

For a combination of rails and ball slides, as shown below, where the assembly is subject only to moment loads, the static load limit is to be reviewed by the basic static moment load rating, but, not by the basic static load rating.
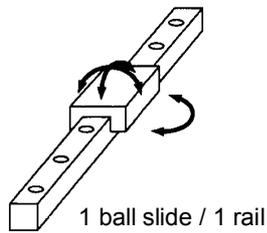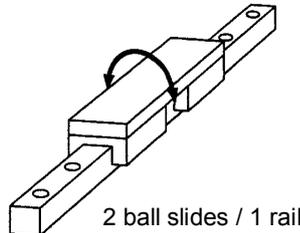
1 ball slide / 1 rail	2 ball slides / 1 rail	2 ball slides / 2 rails
Example 1: All direction	Example 2: Rolling direction	Example 3: Pitching /yawing direction

2 Fatigue life

When a rolling element linear motion bearing travels under a load, the balls and its rolling contact surfaces are constantly subject to repeated load, and this causes scaly damage to ball groove surfaces resulted from material fatigue. This is called "flaking." The total travel distance made by the time of the first flaking to occur is called "fatigue life."

Flaking on ball slide groove

Flaking on rail groove
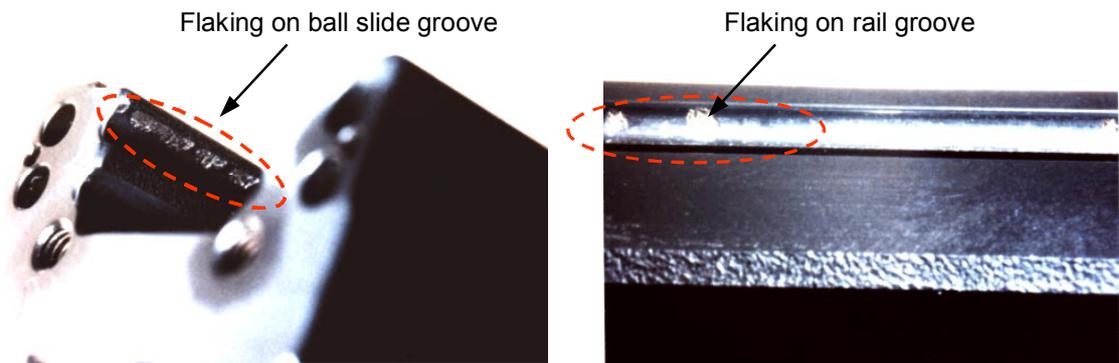
<< Basic dynamic load rating, C>>

The basic dynamic load rating C is defined as a load under which 90% of a group of the same model linear guides, which are running individually, can complete their running over the distance of 50km without flaking. For the case of a linear guide, it is defined as a constant load acting vertically to the center of a ball slide. Such load is listed in the dimension tables in the catalogues.

◆ Relationship among basic dynamic load rating (C), load to ball slide (F) and fatigue life (L)

$$L \propto \left(\frac{C}{F} \right)^3 \qquad \Rightarrow$$

> - When you select a linear guide of which C is twice of the one selected before, fatigue life can extend to eight times more.
>   (Reversely, when C is reduced to 1/2, fatigue life lowers to 1/8.)
> - When load to a ball slide F is increased twice, fatigue life shortens to 1/8.
>   (Reversely, when F is lowered to 1/2, fatigue life extends by eight times.)
>
> $$\Downarrow$$
>
> Namely, a longer fatigue life can be obtained when linear guides with a larger C value are used under smaller loads to a ball slide.

<<Equivalent dynamic load>>

Loads acting on linear guides (loads to a ball slide) can be vertical loads, horizontal loads or moment loads, and, sometimes, combined loads among them could be the case. Besides, they may vary in their size and/or direction. Since you cannot use varying loads directly for life expectancy calculation, an imaginative constant load to a ball slide that could cause a life expectancy equivalent to the actual one is considered. This load is called dynamic equivalent load. In short, loads applied in various directions are all converted into one vertical load to a ball slide. For more information on computation methods for a dynamic equivalent load, refer to the catalogues.
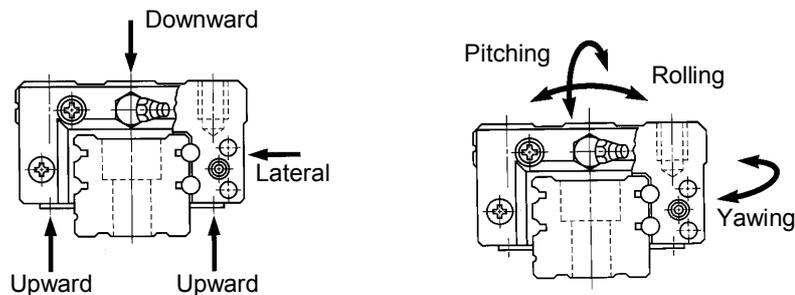
Various loads applied to a ball slide

<<Mean load>>

Among various application conditions of linear guides, there are such cases in which the load (dynamic equivalent load) applied to a ball slide varies while operating. In this case, compute a mean load that gives the ball slide life expectancy equivalent to its actual one under such varying load, and use it as the ball slide load F for life calculation. Accordingly, it is necessary to ask for detailed information on the usage conditions, and collect as much information as possible in order to select most appropriate linear guides and to avoid any troubles as well.

◆ Clipping data ◆ Life of Linear Guide

(1) Use of a linear guide for a long duration deteriorates it, and eventually it becomes unusable, even it has been used properly. The period before a linear guide becomes unusable is called "life" in a broad sense, that can be either "fatigue life" or "accuracy deterioration life."

Accuracy deterioration life:

A period of time that a linear guide reaches its application limit in terms of mechanical performance due to deteriorated accuracy caused by slight yet continuous wear of the rolling contact surfaces. Since the application limits vary depending on the accuracy required for a machine and interrelationship among its components, the definition of the accuracy deterioration life may remain very vague.

(2) If two or more ball slides form a system (such as a table shown below), the life of the system considered to be the life of one of the ball slides that works under the severest conditions.
Assuming that the ball slide A in the figure on the right is subject to the largest mean load (thus causing the shortest life), for example, the life of the entire system is represented by the life of the ball slide A.

---
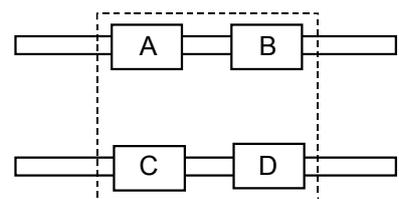
3 Compensation of basic load rating (C and C_0) by load direction

- Basic load ratings of ball slide are listed in the catalogs as basic dynamic load (C) rating and basic static load (C_0) rating, both of which are for the loads in the downward direction. In actual operating conditions, however, loads are also applied in upward and lateral directions, in which cases the rated basic loads are expressed as shown in the table below:

Basic load rating	Basic dynamic load rating			Basic static load rating		
Load direction	Downward	Upward	Sideward	Downward	Upward	Sideward
LH, LS, LW	C	C	0.88C	C_0	0.75 C_0	0.63 C_0
LA, LY, LE, LU, LL	C	C	C	C_0	C_0	C_0

- Some of the series including LY have the same C and C_0 values for all load directions, while other series including LH have different values depending on the load directions. This is derived from some differences in design practices used for contact angle, profile, and arrangement of the grooves.

4 Factors (coefficients) affecting the load limits

◆ Load factor

Although it is possible to calculate loads applied to a ball slide, actual loads will be larger than the calculated values due to vibration of machine or impact that a machine receives. It is therefore necessary, when calculating a fatigue life, to take load factor into consideration.

Impact/Vibration Load	Load factor
No external impact/vibration	1.0 ~1.5
External impact/vibration	1.5 ~ 2.0
Significant external impact or vibration	2.0 ~ 3.0

◆ Hardness coefficient

In order for linear guides to fully achieve their performance, balls and their rolling surfaces must have an appropriate material hardness. Rated load values listed in the catalogues are based on the NSK standard materials with their surface hardness of HRC 58 to 62. If the material used is different from the NSK standard and lower than HRC 58 in its surface hardness, the rated load must be adjusted using a hardness coefficient. Pay due attention whenever the user specifies any material different from NSK standard.

$$C_H = f_H \cdot C$$
$$C_{0H} = f_H' \cdot Co$$

in which
- C_H : Basic dynamic load rating adjusted to hardness;
- f_H : Hardness factor (refer to the Figure shown above);
- C_{OH} : Basic static load rating adjusted for hardness;
- f_H' : Static hardness factor (refer to the Figure shown above).
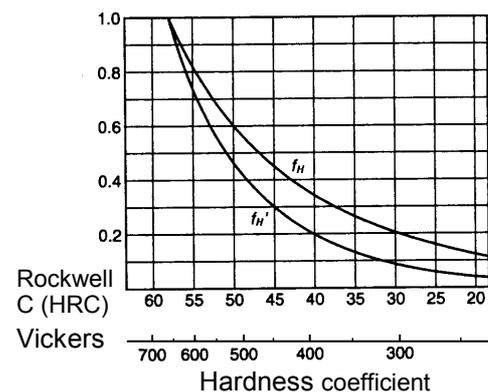
◆ Mounting error

When linear guides are mounted with excessive mounting errors, it will cause forces that will twist ball slides. This might result in a shorter life to such ball slides. The value at which the fatigue life is more than 5 000km under the following conditions is defined as an allowable mounting error.

◊ Applied load per one ball slide is 10% of the basic dynamic load rating, and

◊ No deformation occurs except at contact points of balls

Allowable mounting errors as shown in the following illustrations are set as the engineering standards. For more detailed information on the data, refer to the catalog (No. E3155, page A178).
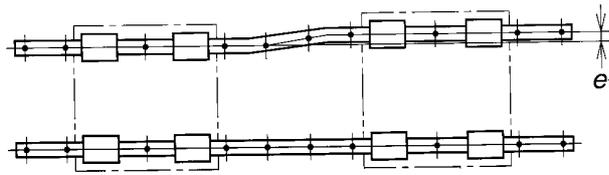
Inclination of two rails: e_1 Inclination of two rails: e_2
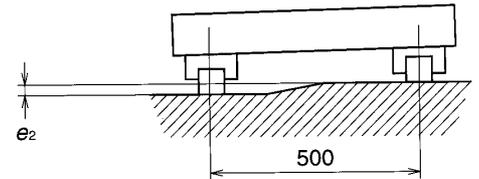
Lesson 2: Selecting Procedure of Linear Guides

This section provides how to select a linear guide in general. Please use the catalog "Precision Machine Components" (catalogue number E3155) for the reference material.

Section 1 | Selecting Flowchart

The general selection procedures for linear guides are shown in the following flowchart.

| Confirmation of use conditions | ← | • Application • Stroke
• Machine structure • Load condition
• Mounting space for linear guide
• Speed • Mounting position
• Required life, rigidity; and accuracy
• Frequency of use (duty cycle, etc)
• Environment, etc. |

⇩

Selection of model (series)

⇩

| Selection of model number | ← | • Selection from mounting space
• Selection based on expertise
• Selection from rough figures of load/ball slide |

⇩

NG ← Calculation of fatigue life ⇨ Refer to Section 2 for details.

⇩ OK

NG ← | Preload selection (Study of rigidity) | ← | Study deflection on the working point of load. |

⇩ OK

Decision of accuracy

⇩

| Lubrication, dustproof, surface treatment | ← | • Selection from mounting space
• Selection based on expertise
• Selection from rough figures of load/ball slide |

⇩

End of selection

Section 2 | Calculation Flowchart of Fatigue Life

This section provides the calculation flowchart of fatigue life.

Study of use conditions	You need to identify the following conditions to find out working load to a ball slide, and, thereby, to calculate the fatigue life. • Configuration of axes • Combination of rail (Single rail, multiple rails) • Load value (Direction in X, Y, and Z of coordinates axis) • Span of ball slides • Span of rails • Working point of the load (X, Y, and Z coordinates) • Position of driving device (position of ball screw, etc.) 　　　　　　　　　　　(X, Y, and Z coordinates) • Feed speed • Start up time • Frequency of use (Duty cycle)
⇩	
Load calculation of each ball slide	
⇩	
Calculation of equivalent dynamic	Calculate load to each ball slide installed in a machine. Refer to the catalog of "Precision Machine Component (cat. No. E155)" for detail of the formula.
⇩	
Calculation of mean load	
⇩ OK	
Selection on load factor	
⇩ OK	
Estimation of fatigue life	
⇩	
Check for static load	Confirm that the static load is in the allowable range.
⇩	
End.	

Section 3 | Cares to Be Exercised When Selecting a Linear Guide

In the following cases, take due cares for the selection of a linear guide. Please collect detailed information, and consult with NSK's Engineering Department.

1 Where oscillating motions are involved

When a linear guide repeats a short stroke of less than a half rotation of a ball at high frequency (oscillating motions), lubricant tends to get removed from the contact area of the rolling ball and the ball groove surface (loss of oil film). This will cause direct metal to metal contact between the balls and the ball grooves, and will result in premature abrasion called fretting.

Check whether there are any oscillating motions involved or not, whenever customer's service conditions are presented.

⇩　　There is no absolute preventive measure against fretting, but it is possible to ease down its progress.

● Use anti-fretting grease.

● If standard grease is used, add a long stroke of movement (longer than the ball slide length) once every several thousand cycles.

2 Where a moment load in a pitching or yawing direction is applied

This will induce uneven loads to the rows of balls inside the ball slide, affecting excessive large loads on the balls located closest to the ends (edge load).

2 rails / 2 ball slides
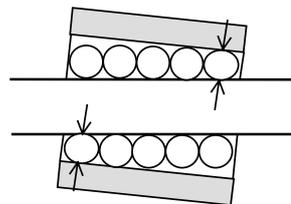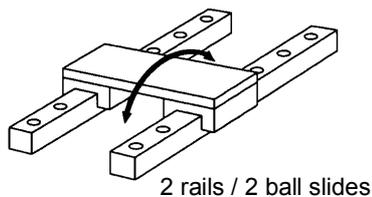
An imaginary illustration of the application of a moment load in a yawing direction

⇩

● Use grease for high load applications or oil lubricant.

● Use a linear guide one size larger to reduce contact pressure applied to individual balls.

3 Where an extremely large load is applied during a stroke at the same point

If an extremely large load is applied at a certain point of strokes, the fatigue life may become extremely shorter than that of normal conditions. This is because such load causes a large local stress (surface pressure) generated on the contact surfaces between the balls and the ball grooves, which makes the fatigue life shorter.

⇩

● Take the possible contact pressure into consideration when estimating the fatigue life.

4 When calculation result of fatigue life is extremely low (lower than 3 000 km)

Since a contact pressure between the ball and raceway surface is quite large in this case, the actual fatigue life might become much shorter than the calculated one, affected by lubrication or debris if used always under such conditions.

⇩

● Review number, arrangement and model numbers of ball slide to lower the load for a ball slide.

Section 4 | Selection Example

Let's select a linear guide and estimate its fatigue life that is installed on a single axis transport system shown below.

1 Use condition

- Application: Transport system

- Structure: See right illustration

- Mounting position: Horizontal

- Mounting arrangement of the liner guides
  Ball slide span Lb : 600 mm
  Rail span Lr　　　: 500 mm

- Load conditions
  Table mass W1 : 600 N
  Load mass W2 : 2400 N

- Coordinates of the load acting point

Load	X coordinate	Y coordinate	Z coordinate
W1	30	-20	80
W2	250	-300	500

- The table carries the load only in one direction.

- Stroke: 1500 mm (1 cycle: 3 000mm)

- Maximum speed: 30 m/min.

- Duration of startup acceleration: 1 sec.

- Operating hour: 16 hours/day

- Environment: 10 ~ 30 °C
  (Normal ambient condition, not in high humidity, and no contamination)
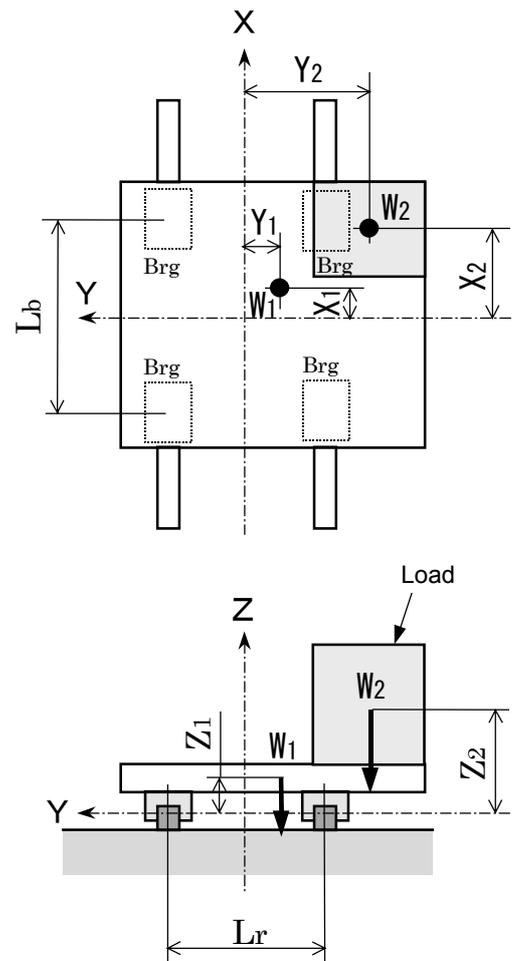
2 Selection of linear guide type (Series)

Select the type of linear guide suitable for the application referring to Table 1.2.1. "Classification of NSK linear guides" on page A9 of "Precision Machine Components (CAT. No.E3155)." Chose LH or LS series because it fits to an arrangement of 4 ball slides on 2 rails for the transport equipment (material handling).

3 Selection of model size

Select size (model number) referring to "A-I-3.2. Selection of Linear Guide Size, (3) Select the size based on the estimated load on one ball slider" on page A17 of the catalog "Precision Machine Component (CAT.No.E3155)."

◆ Calculation of an approximate load P per ball slide

Calculate load position coefficient Kp1 and Kp2 for vertical loads of W1 and W2 respectively.

● Load position coefficient Kp1 of W1 is

$$K_{p1} = \left| \frac{X_1}{L_b} \right| + \left| \frac{Y_1}{L_r} \right| = \frac{30}{600} + \frac{20}{500} = 0.09$$

● Load position coefficient Kp2 of W2 is

$$K_{p2} = \left| \frac{X_2}{L_b} \right| + \left| \frac{Y_2}{L_r} \right| = \frac{250}{600} + \frac{300}{500} = 1.02$$

Approximate load P to a ball slide shall be obtained from the load position coefficients above.

$$
\begin{aligned}
P &= \sum \frac{F}{4} + \sum \frac{K_p \cdot F}{2} \\
&= \frac{W_1 + W_2}{4} + \frac{K_{p1} \cdot W_1 + K_{p2} \cdot W_2}{2} \\
&= \frac{600 + 2400}{4} + \frac{0.09 \times 600 + 1.02 \times 2400}{2} \\
&= 2001 \, (N)
\end{aligned}
$$

◆ Choice of the size

Choose LS30AL from Figure I-3•4 "Selection based on the load" on page A19 of "Precision Machine Components (CAT. No. E3155)."
(Refer to the next page.)
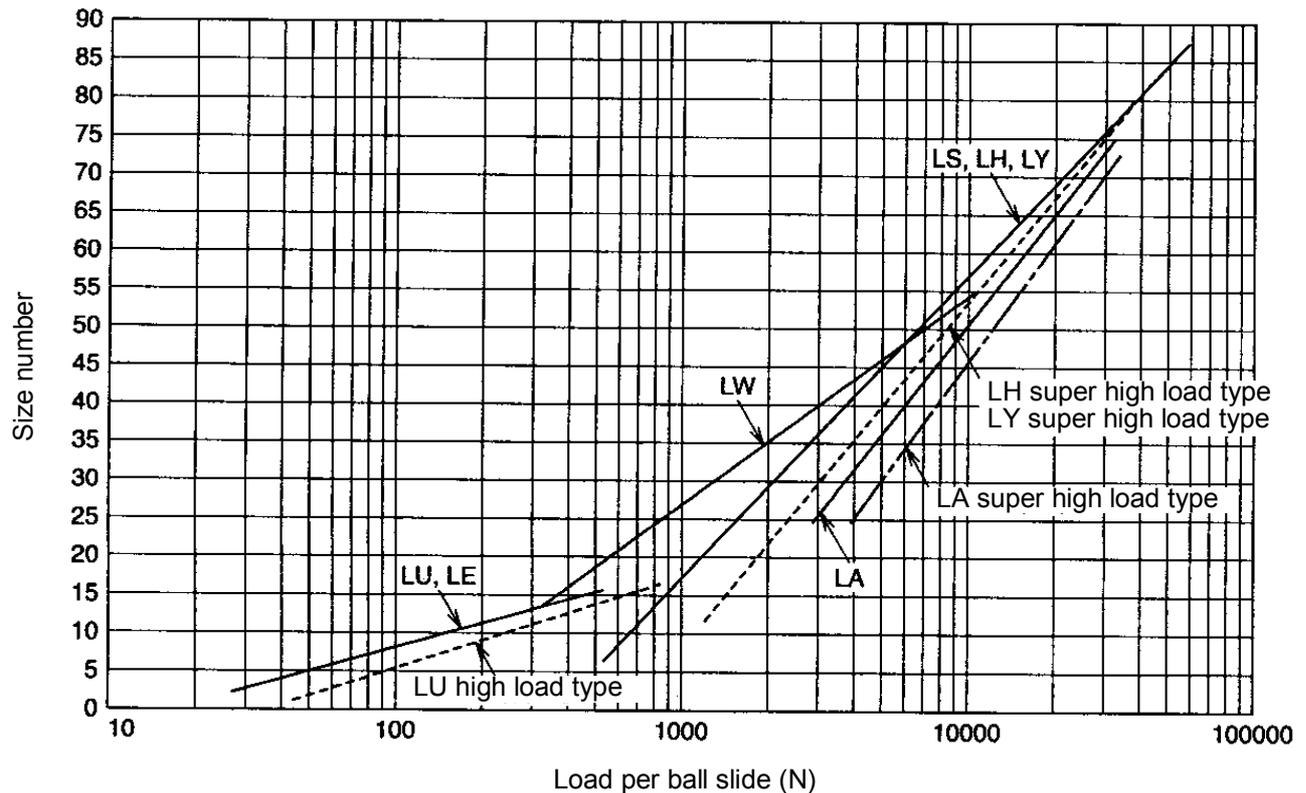
Selection based on the load

[Fig. I-3•4 on Page A19 of the catalog "Precision Machine Components (CAT. No. E3155)"]

4 Calculation of fatigue life

Calculate the fatigue life of selected linear guide LS30AL following "A-II-3.2. How to Calculate Life" on page A145 of "Precision Machine Components (CAT. No. E3155)."

- Linear guide S30AL   : Basic dynamic load rating   :23400 N
                         : Basic static load rating   :43000 N

- Use conditions of linear guide   : Remain same as stated on the part [1] above.
  We don't need to consider the inertial force due to the mass of carrying load and table weight because the acceleration of 0.5 m/sec^2 (0.05G), that is obtained by the maximum speed and accelerating time, is so low that we could disregard its influence.

◆ **Calculation of the load that is acting on a ball slide**

You need to calculate two cases of load conditions: one is for when the linear guides are loaded (moving outward), and the other is for when returning unloaded (moving backward).
Usually, "Table II-3.2: Load Pattern 4 acting upon ball slide" provided in Page A147, "Precision Machine Components" catalog (CAT. No. E3155) is used. However, for this example, we simply need to calculate substituting Fxi = Fyj = 0, since only two vertical loads, W1 and W2 (= F_{Zk}), are involved.

(1) When the linear guide is loaded: (moving outward)

$$M1 = \sum_{k=1}^{n} (F_{zk} \cdot Y_{zk})$$
$$= W_1 \cdot Y_1 + W_2 \cdot Y_2$$
$$= 600 \times (-20) + 2400 \times (-300)$$
$$= -732000 \; (N \cdot mm)$$

$$M2 = \sum_{k=1}^{n} (F_{zk} \cdot X_{zk})$$
$$= W_1 \cdot X_1 + W_2 \cdot X_2$$
$$= 600 \times 30 + 2400 \times 250$$
$$= 618000 \; (N \cdot mm)$$

$$F_{r1} = \frac{\sum_{k=1}^{n} F_{zk}}{4} + \frac{M1}{2L_r} + \frac{M2}{2L_b}$$
$$= \frac{W_1 + W_2}{4} + \frac{M1}{2L_r} + \frac{M2}{2L_b}$$
$$= \frac{600 + 2400}{4} + \frac{-732000}{2 \times 500} + \frac{618000}{2 \times 600}$$
$$= 533 \; (N)$$

Similarly,

$$F_{r2} = -497 \; (N)$$
$$F_{r3} = 1997 \; (N)$$
$$F_{r4} = 967 \; (N)$$

(2) When no load is applied to the linear guide (moving backward)

$$M1 = \sum_{k=1}^{n} (F_{zk} \cdot Y_{zk})$$
$$= W_1 \cdot Y_1$$
$$= 600 \times (-20)$$
$$= -12000 \ (N \cdot mm)$$

$$M2 = \sum_{k=1}^{n} (F_{zk} \cdot X_{zk})$$
$$= W_1 \cdot X_1$$
$$= 600 \times 30$$
$$= 18000 \ (N \cdot mm)$$

$$F_{r1} = \frac{\sum_{k=1}^{n} F_{zk}}{4} + \frac{M1}{2L_r} + \frac{M2}{2L_b}$$
$$= \frac{W_1}{4} + \frac{M1}{2L_r} + \frac{M2}{2L_b}$$
$$= \frac{600}{4} + \frac{-12000}{2 \times 500} + \frac{18000}{2 \times 600}$$
$$= 153 \ (N)$$

Similarly,

$$F_{r2} = 123 \ (N)$$
$$F_{r3} = 177 \ (N)$$
$$F_{r4} = 147 \ (N)$$

Table below shows the above results.

Load to ball slide (vertical)   [Unit: N]

	Load applied (moving outward)	No load applied (moving backward)
Ball slide 1	533	153
Ball slide 2	-497	123
Ball slide 3	1997	177
Ball slide 4	967	147

◆ Calculation of dynamic equivalent load

For this example, you do not need to calculate dynamic equivalent load because the direction of load to ball slides are vertical only.

◆ Calculation of mean effective load

Calculate mean effective load referring to the catalog "Precision Machine Components (CAT. No. E3155) Page A152, (5) Calculation of mean effective load." Obtain a mean effective load of ball slide 3 of which load condition is the hardest.

Load to ball slide

Fe1

1997 (N)

Fe1

177 (N)

0   Outwar   150   Backwar   0 (mm)

Load cycle pattern
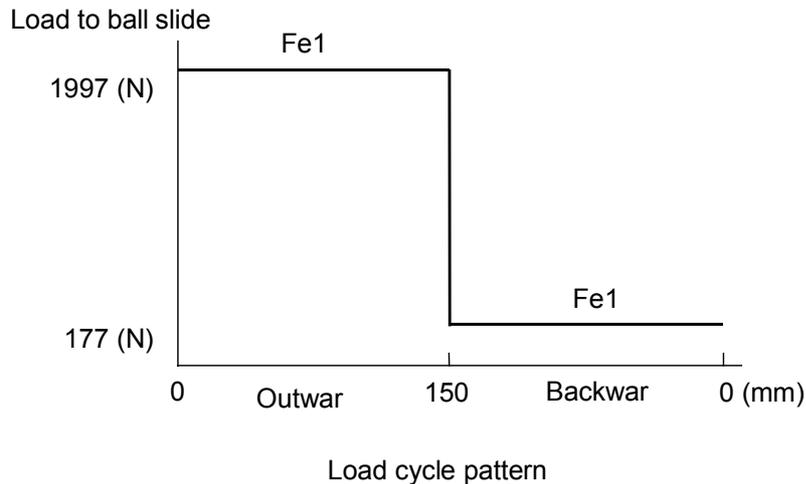
You can have the mean effective load by an equation below as the load pattern fits "(1) When the load and running distance vary stepwise" in Page A162 of the catalog.

For this example,   L＝ L1 + L2

$$F_m = \sqrt[3]{\frac{1}{L}\left(F_{e1}^3 \cdot L_1 + F_{e2}^3 \cdot L_2\right)}$$

$$= \sqrt[3]{\frac{1}{3000}\left(1997^3 \times 1500 + 177^3 \times 1500\right)}$$

$$= 1585 \ (N)$$

◆ Determination of various coefficients

(1) Load factor

The load factor f_W shall be 1.0 to 1.5 because the operation of the table will be very moderate since the maximum speed is 30 m/min, and startup acceleration is 5 m/sec² (0.05G). So, for this case, we take 1.2 that is commonly used value.

(2) Hardness coefficient

The hardness coefficient f_H shall be 1.0 as the standard material of NSK is used. Take the basic dynamic load rating as listed on the catalog.

◆ Calculate fatigue life

- Basic dynamic load rating C of LS30AL (selected linear guide): 23400 (N)

- Mean effective load F_m: 1585 (N)

- Load factor f_w: 1.2

- Hardness coefficient f_H: 1.0

- Fatigue life : L (km)

$$
\begin{aligned}
L &= 50 \times \left(\frac{f_H \cdot C}{f_w \cdot F_m} \right)^3 \\
&= 50 \times \left(\frac{1 \times 23400}{1.2 \times 1585} \right)^3 \\
&= 93100 \ (km)
\end{aligned}
$$

Assuming that the mean travel speed is 3 m/min, and that the operation time is 16 hr/day, the fatigue life calculated above can be converted into a unit of time duration as follows;

$$
\begin{aligned}
L_t &= \frac{93100 \times 1000}{3 \times 60 \times 16} \\
&= 32320 \ (days)
\end{aligned}
$$

◆ Studies on Static Load

Study the static load on Ball slide 3 in which the loads are the largest. From the basic static load rating Co of 43 000 (N) for the selected linear guide LS30AL, its static permissible load factor f_s is

$$
f_s = \frac{C_0}{P_0} = \frac{43000}{1997} = 21.5
$$

Therefore, the static permissible load factor is satisfactory.

5 Selection of preload and accuracy grade

As given in "Application Examples of Precision Grades and Preloads" in Lesson 1, Section 1, select the accuracy grade PC (regular) and preload ZT (fine clearance) since this example's application is a transport equipment and, we take into account its maintenance properties, availability and so forth.

6 Lubrication, dust protection and surface treatment

The example case is used at regular room temperature in environment neither with dusts nor in high humidity – a quite regular environment. So, we select standard linear guides.

From all results above, our selections shall be;

- Accuracy grade : PC

- Ball slide : LA30AL (four pieces)

- Rails : L1S302280 (two pieces)
  : [Total rail length 2 280 mm = [1 500 (stroke) + 600 (bearing span) + 96.4 (ball slide length) + α (minimum allowance) = 2 280]