Features of the LM Guide

Functions Required for Linear Guide Surface	
Large permissible load	Smooth motion with no clearance
Highly rigid in all directions	Superbly high speed
High positioning repeatability	Easy maintenance
Running accuracy can be obtained easily	Can be used in various environments
High accuracy can be maintained over a long period	

Features of the LM Guide

- Large permissible load and high rigidity
- Accuracy averaging effect by absorbing mounting surface error
- Ideal four raceway, circular-arc groove, two point contact structure
- Superb error-absorbing capability with the DF design
- Low friction coefficient
- Wide array of options (QZ lubricator, Laminated contact scraper LaCS, etc.)

As a result, the following features are achieved.

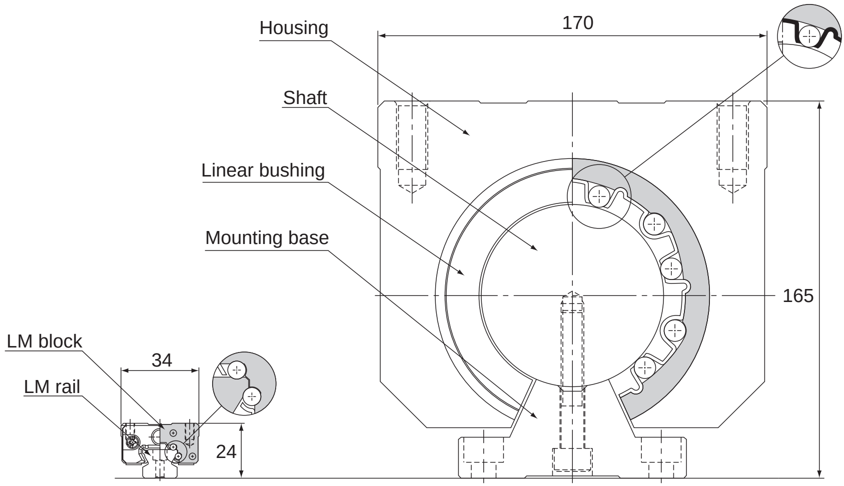
Easy maintenance
Improved productivity of the machine
Substantial energy savings
Low total cost
Higher accuracy of the machine
Higher efficiency in machine design

Large Permissible Load and High Rigidity

[Large Permissible Load]

The LM Guide has raceway grooves with a radius almost equal to the ball radius, which is significantly different from the linear bushing. As shown in Fig.1, which compares size between the LM Guide and the linear bushing with similar basic dynamic load ratings, the LM Guide is much smaller than the linear bushing, indicating that the LM Guide allows a significantly compact design.

The reason for this space saving is the greater difference in permissible load between the R-groove contact structure and the surface contact structure. The R-groove contact structure (radius: 52% of the ball radius) can bear a load per ball 13 times greater than the surface contact structure. Since service life is proportional to the cube of the permissible load, this increased ball-bearing load translates into a service life that is approximately 2,200 longer than the linear bushing.



LM Guide model SSR15XW
Basic dynamic load rating: 14.7 kN

Linear Bushing model LM80 OP
Basic dynamic load rating: 7.35 kN

Fig.1 Comparison between the LM Guide and the Linear Bushing

Table1 Load Capacity per Ball (P and P_1)
Permissible contact surface pressure: 4,200 MPa

	R-groove (P)	Flat surface (P_1)	P/P_1
ϕ 3.175 (1/8´´)	0.90 kN	0.07 kN	13
ϕ 4.763 (3/16´´)	2.03 kN	0.16 kN	13
ϕ 6.350 (1/4´´)	3.61 kN	0.28 kN	13
ϕ 7.938 (5/16´´)	5.64 kN	0.44 kN	13
ϕ 11.906 (15/32´´)	12.68 kN	0.98 kN	13

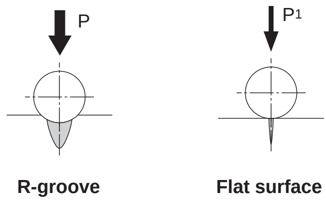


Fig.2 Load Capacity per Ball

[High Rigidity]

The LM Guide is capable of bearing vertical and horizontal loads. Additionally, due to the circular-arc groove design, it is capable of carrying a preload as necessary to increase its rigidity.
When compared with a feed screw shaft system and a spindle in rigidity, the guide surface using an LM Guide has higher rigidity.

● Example of comparing static rigidity between the LM Guide, a feed screw shaft system and a spindle

(vertical machining center with the main shaft motor of 7.5 kW)

[Components]

LM Guide: SVR45LC/C0
(C0 clearance: preload = 11.11kN)
Ball Screw: BNFN4010-5/G0
(G0 clearance: preload = 2.64kN)
Spindle: general-purpose cutting spindle

Table2 Comparison of Static Rigidity

Unit: N/μm

Components	X-axis direction	Y-axis direction	Z-axis direction
LM Guide	—	2400	9400 (radial) 7400 (reverse radial)
Ball screw	330	—	—
Spindle	250	250	280

Note) The rigidity of the feed screw shaft system includes rigidity of the shaft end support bearing.

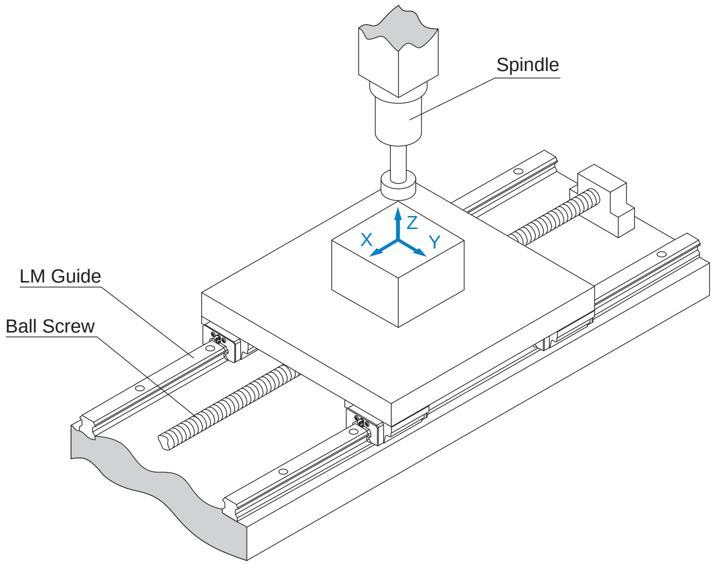
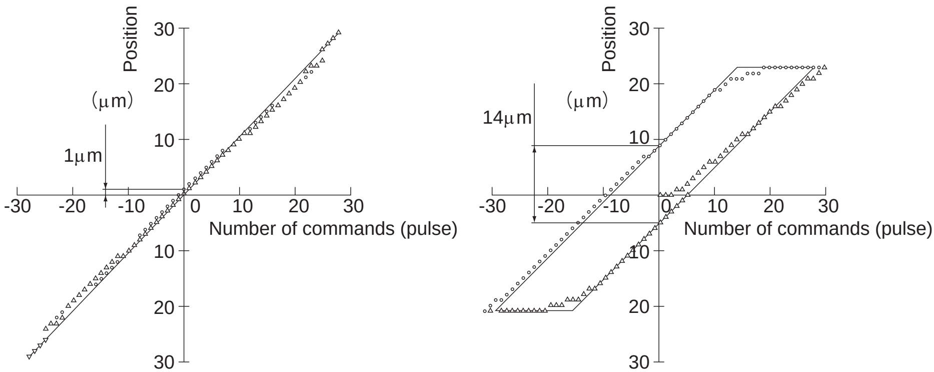


Fig.3

High Precision of Motion

[Small lost motion]

The LM Guide is provided with an ideal rolling mechanism. Therefore, the difference between dynamic and static friction is minimal and lost motion hardly occurs.



LM Guide model HSR45

Square slide + Turcite

(Measurements are taken with the single-axis table loaded with a 500-kg weight)

Fig.4 Comparison of Lost Motion between the LM Guide and a Slide Guide

Table3 Lost Motion Comparison

Unit: μm

Type	Clearance	Test method			
		As per JIS B 6330			Based on minimum unit feeding
		10mm/min	500mm/min	4000mm/min	
LM Guide (HSR45)	C1 clearance (see table below)	2.3	5.3	3.9	0
	C0 clearance (see table below)	3.6	4.4	3.1	1
Square slide + turcite	0.02mm	10.7	15	14.1	14
	0.005mm	8.7	13.1	12.1	13

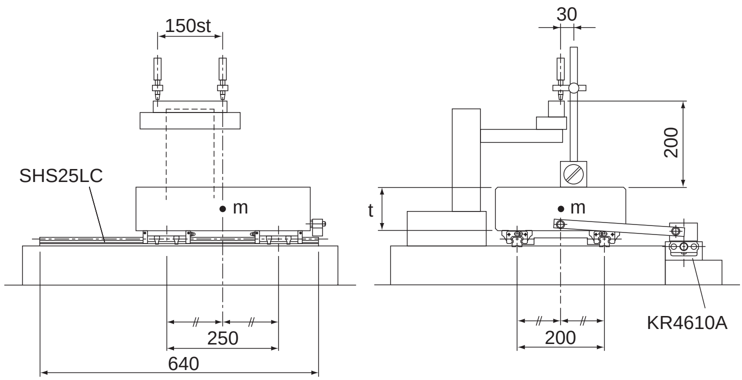
Radial clearance of the LM Guide

Unit: μm

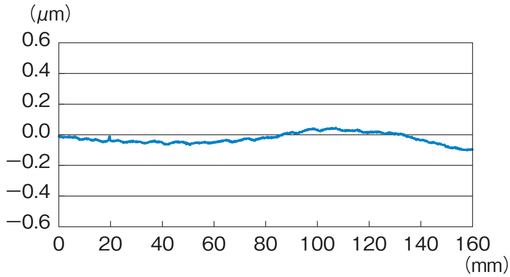
Symbol	C1	C0
Radial clearance	–25 to –10	–40 to –25

[High running accuracy]
Use of the LM Guide allows you to achieve high running accuracy.

[Measurement method]



Pitching accuracy



Yawing accuracy

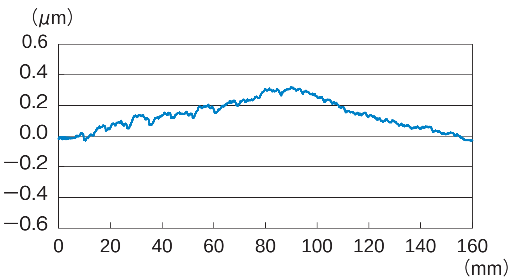


Fig.5 Dynamic Accuracy of a Single-axis Table

[High accuracy maintained over a long period]

As the LM Guide employs an ideal rolling mechanism, wear is negligible and high precision is maintained for long periods of time. As shown in Fig.6, when the LM Guide operates under both a preload and a normal load, more than 90% of the preload remains even after running 2,000 km.

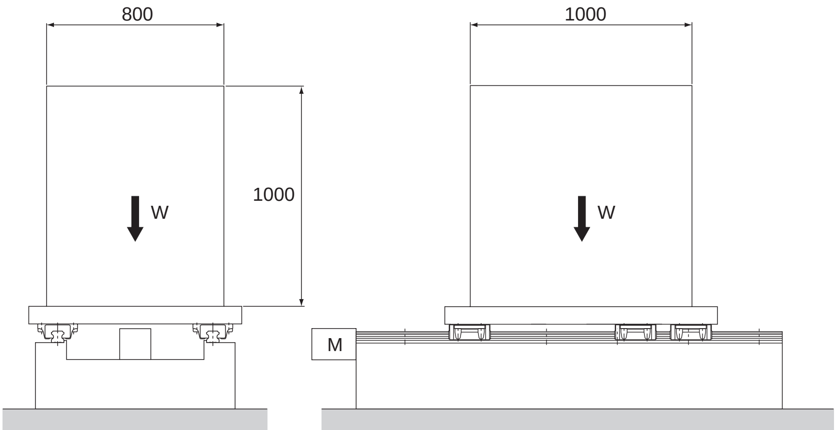


Fig.6 Condition

[Conditions]

Model No. : HSR65LA3SSC0 + 2565LP-Ⅱ

Radial clearance

: C0 (preload: 15.7 kN)

Stroke : 1,050mm

Speed : 15 m/min (stops 5 sec at both ends)

Acceleration/decelelation time in rapid motion

: 300 ms (acceleration: α = 0.833 m/s^2)

Mass : 6000kg

Drive : Ball Screws

Lubrication : Lithium soap-based grease No. 2 (greased every 100 km)

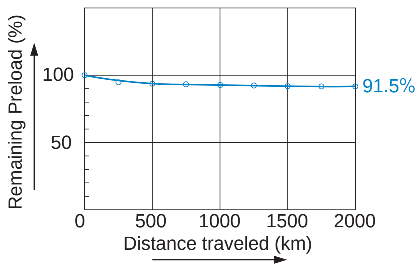


Fig.7 Distance Traveled and Remaining Preload

Accuracy Averaging Effect by Absorbing Mounting Surface Error

The LM Guide contains highly spherical balls and has a constrained structure with no clearance. In addition, it uses LM rails in parallel on multiple axes to form a guide system with multiple-axis configuration. Thus, the LM Guide is capable of absorbing misalignment in straightness, flatness or parallelism that would occur in the machining of the base to which the LM Guide is to be mounted or in the installation of the LM Guide by averaging these errors.

The magnitude of the averaging effect varies according to the length or size of the misalignment, the preload applied on the LM Guide and the number of axes in the multiple-axis configuration. When misalignment is given to one of the LM rails of the table as shown in Fig.8, the magnitude of misalignment and the actual dynamic accuracy of the table (straightness in the horizontal direction) are as shown in Fig.9.

By applying such characteristics obtained with the averaging effect, you can easily establish a guide system with high precision of motion.

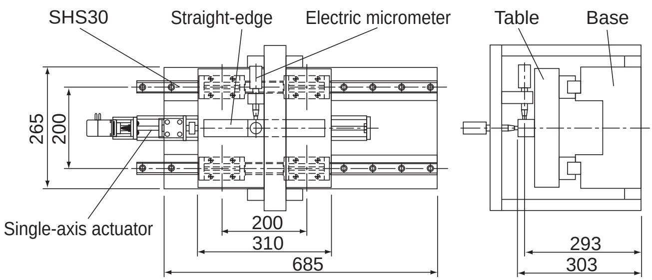


Fig.8

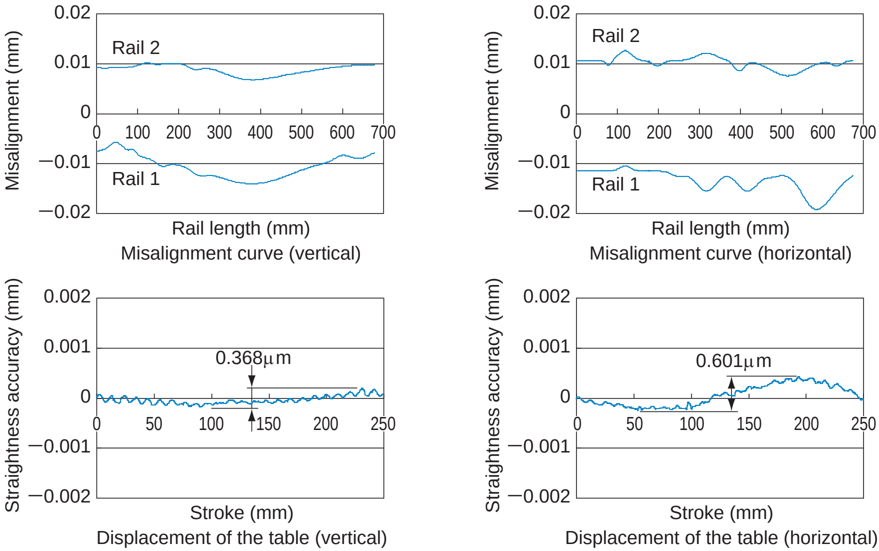


Fig.9

Even on a roughly milled mounting surface, the LM Guide drastically increases running accuracy of the top face of the table.

[Example of Installation]

When comparing the mounting surface accuracy (a) and the table running accuracy (b), the results are :

Vertical	92.5µm	→	15µm	=	1/6
Horizontal	28µm	→	4µm	=	1/7

Table4 Actual Measurement of Mounting-Surface Accuracy

Unit: µm

Direction	Mounting surface		Straightness	Average (a)
Vertical	Horizontal	A	80	92.5
		B	105	
Bottom surface	Side surface	C	40	28
		D	16	

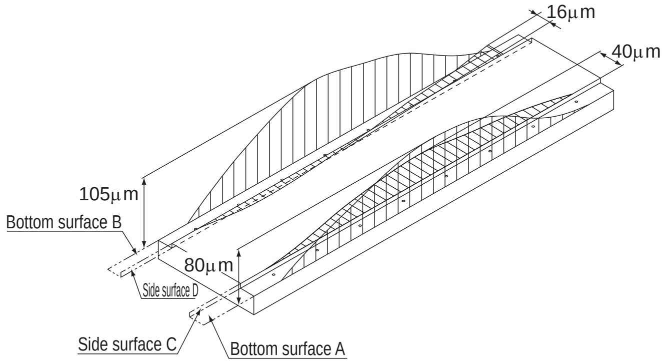


Fig.10 Surface Accuracy of the LM Guide Mounting Base (Milled Surface Only)

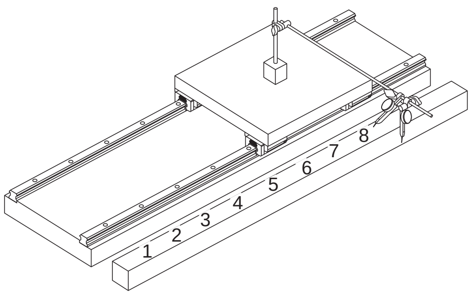


Fig.11 Running Accuracy After the LM Guide Is Mounted

Table5 Actual Measurement of Running Accuracy on the Table (Based on Measurement in Fig.10 and Fig.11)

Unit: µm

Direction	Measurement point								
	1	2	3	4	5	6	7	8	Straightness (b)
Vertical	0	+2	+8	+13	+15	+9	+5	0	15
Horizontal	0	+1	+2	+3	+2	+2	−1	0	4

Easy Maintenance

Unlike with sliding guides, the LM Guide does not incur abnormal wear. As a result, sliding surfaces do not need to be reconditioned, and precision needs not be altered. Regarding lubrication, sliding guides require forced circulation of a large amount of lubricant so as to maintain an oil film on the sliding surfaces, whereas the LM Guide only needs periodical replenishing of a small amount of grease or lubricant. Maintenance is that simple. This also helps keep the work environment clean.

Substantial Energy Savings

As shown in Table6, the LM Guide has a substantial energy saving effect.

Table6 Comparative Data on Sliding and Rolling Characteristics

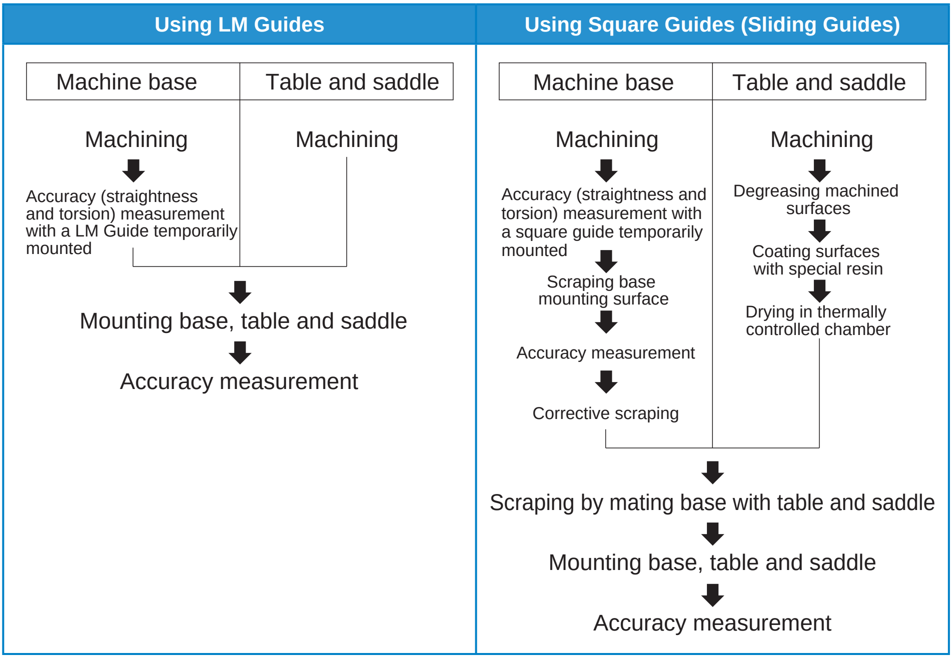
Machine Specifications		
Type of machine	Single-axis surface grinding machine (sliding guide)	Three-axis surface grinding machine (rolling guide)
Overall length × overall width	13m×3.2m	12.6m×2.6m
Total mass	17000kg	16000kg
Table mass	5000kg	5000kg
Grinding area	0.7m×5m	0.7m×5m
Table guide	Rolling through V-V guide	Rolling through LM Guide installation
No. of grinding stone axes	Single axis (5.5 kW)	Three axes (5.5 kW + 3.7 kW x 2) Grinding capacity: 3 times greater

Table Drive Specifications			Ratio
Motor used	38.05kW	3.7kW	10.3
Drive hydraulic pressure	Bore diameter ϕ 160×1.2MPa	Bore diameter ϕ 65×0.7MPa	—
Thrust	23600N	2270N	10.4
Electric Power consumption	38kWH	3.7kWH	10.3
Drive hydraulic pressure oil consumption	400ℓ/year	250ℓ/year	1.6
Lubricant consumption	60 ℓ/year (oil)	3.6 ℓ/year (grease)	16.7

Low Total Cost

Compared with a sliding guide, the LM Guide is easier to assemble and does not require highly skilled technicians to perform the adjustment work. Thus, the assembly man-hours for the LM Guide are reduced, and machines and systems incorporating the LM Guide can be produced at lower cost. The figure below shows an example of difference in the procedure of assembling a machining center between using siding guides and using LM Guides.
Normally, with a sliding guide, the surface on which the guide is installed must be given a very smooth finish by grinding. However, the LM Guide can offer high precision even if the surface is milled or planed. Using the LM Guide thus cuts down on machining man-hours and lowers machining costs as a whole.

[Assembly Procedure for a Machining Center]



When extremely high precision is not required (e.g., running accuracy), the LM Guide can be attached to the steel plate even if the black scale on it is not removed.

Ideal Four Raceway, Circular-Arc Groove, Two-Point Contact Structure

The LM Guide has a self-adjusting capability that competitors' products do not have.
This feature is achieved with an ideal four raceway, circular-arc groove, two-point contact structure.

[Comparison of Characteristics between the LM Guide and Similar Products]

LM Guide: Four Raceway, Circular-arc Groove, Two-point Contact Structure	Other Product: Two-row, Gothic-arch Groove Four Point Contact Structure

LM Guide Model HSR

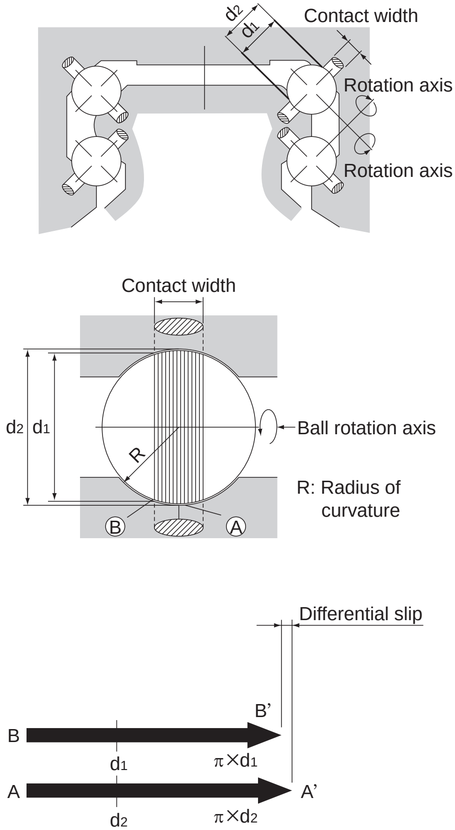


Fig. 12

Two-row Gothic-arch groove product

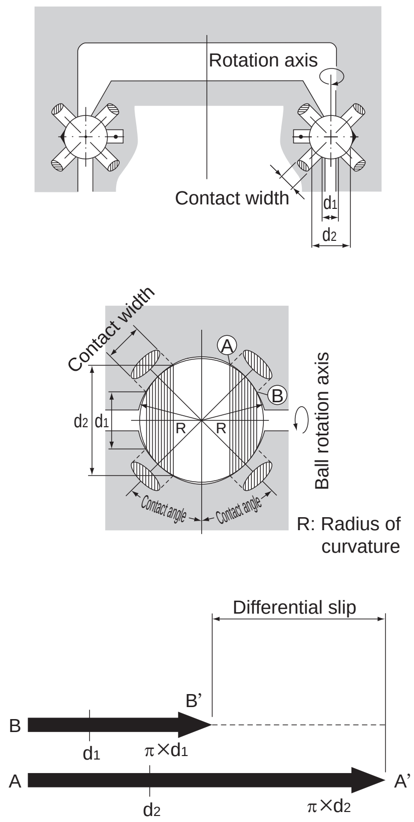


Fig. 13

As indicated in Fig. 12 and Fig. 13, when the ball rotates one revolution, the ball slips by the difference between the circumference of the diameter of inner surface (πd_1) and that of the outer contact diameter (πd_2). (This slip is called differential slip.) If the difference is large, the ball rotates while slipping, the friction coefficient increases more than 10 times and the friction resistance steeply increases.

Four Raceway, Circular-Arc Groove, Two-Point Contact Structure	Two-Row, Gothic-Arch Groove, Four Point Contact Structure
Smooth Motion	
Since the balls contact the raceway at two points in the load direction as shown in Fig. 12 and Fig. 13 on **B1-19** whether under preload or normal load, the difference between d_1 and d_2 is small, as is the differential slip, allowing a smooth rolling motion.	The difference between d_1 and d_2 in the contact area is large as shown in Fig. 12 and Fig. 13 on **B1-19**. Therefore, if any of the following occurs, the ball will generate differential slip, causing friction almost as large as sliding resistance and shortening the service as a result of abnormal friction. (1) A preload is applied (2) A lateral load is applied. (3) If two or more rails are mounted and they are not properly aligned (4) If spinning occurs
Accuracy of the Mounting Surface	
In the ideal two-point contact structure, four rows of circular arc grooves are given appropriate contact angles. With this structure, a light distortion of the mounting surface would be absorbed within the LM block due to elastic deformation of the balls and moving of the contact points to allow unforced, smooth motion. This eliminates the need for a robust mounting base with high rigidity and accuracy for machinery such as a conveyance system.	With the Gothic-arch groove product, each ball contacts the groove at four points, preventing itself from being elastically deformed and the contact points from moving (i.e., no self-adjusting capability). Therefore, even a slight distortion of the mounting surface or an accuracy error of the rail bed cannot be absorbed and smooth motion cannot be achieved. Accordingly, it is necessary to machine a highly rigid mounting base with high precision and mount a high precision rail.
Rigidity	
With the two-point contact, even if a relatively large preload is applied, the rolling resistance does not abnormally increase and high rigidity is obtained.	Since differential slip occurs due to the four-point contact, a sufficient preload cannot be applied and high rigidity cannot be obtained.
Load Rating	
Since the curvature radius of the ball raceway is 51 to 52% of the ball diameter, a large rated load can be obtained.	Since the curvature radius of the Gothic-arch groove has to be 55 to 60% of the ball diameter, the rated load is reduced to approx. 50% of that of the circular arc groove.

Difference in Rigidity

As shown in Fig.14, the rigidity widely varies according to the difference in curvature radius or difference in preload.

Curvature radius and rigidity

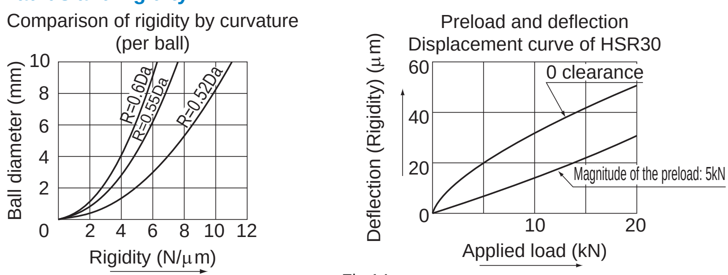


Fig.14

Difference in Service Life

Since the load rating of the gothic arch groove is reduced to approx. 50% of that of the circular arc groove, the service life also decreases to 87.5%.

[Accuracy Error of the Mounting Surface and Test Data on Rolling Resistance]

The difference between the contact structures translates into a rolling resistance.
In the gothic arch groove contact structure, each ball contacts at four points and differential slip or spinning occurs if a preload is applied to increase rigidity or an error in the mounting precision is large. This sharply increases the rolling resistance and causes abnormal wear in an early stage.
The following are test data obtained by comparing an LM Guide having the four raceway, circular-arc groove two-point contact structure and a product having the two-row, Gothic-arch, four-point contact structure.

[Sample]

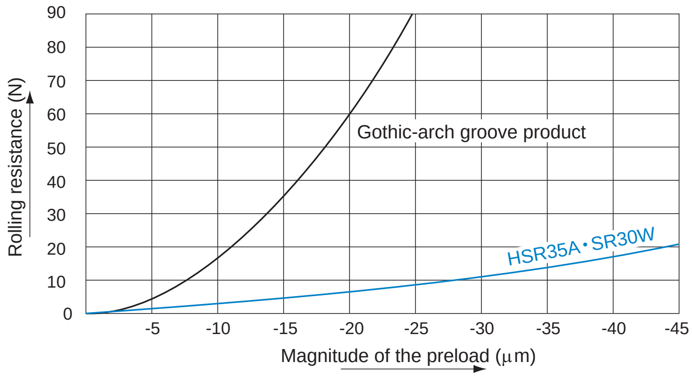
(1) LM Guide
SR30W (radial type) 2 sets
HSR35A (4-way equal-load type) 2 sets
(2) Two-row Gothic-arch groove product
Type with dimensions similar to HSR30 2 sets

[Conditions]

Radial clearance: ±0μm
Without seal
Without lubrication
Load: table mass of 30 kg

Data 1: Preload and rolling resistance

When a preload is applied, the rolling resistance of the Gothic-arch groove product steeply increases and differential slip occurs. Even under a preload, the rolling resistance of the LM Guide does not increase.



Data 2: Error in parallelism between two axes and rolling resistance

As shown in the Fig.15, part of the rails mounted in parallel is parallelly displaced and the rolling resistance at that point is measured.
With the Gothic-arch groove product, the rolling resistance is 34 N when the parallelistic error is 0.03 mm and 62 N when the error is 0.04 mm. These resistances are equivalent to the slip friction coefficients, indicating that the balls are in sliding contact with the groove.

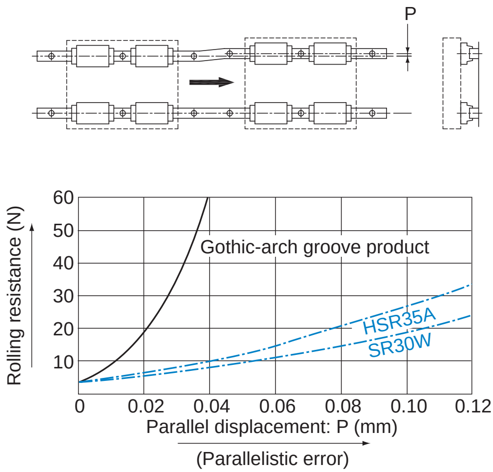
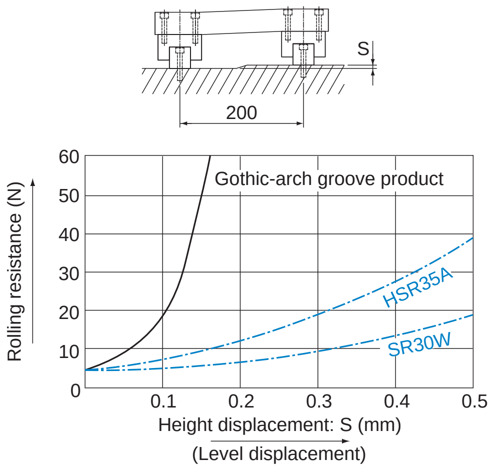


Fig.15

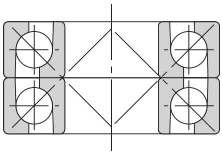
Data 3: Difference between the levels of the top and bottom rails and rolling resistance

Displace the bottom of either rail vertically by S and create the height difference between the two axes. Then, measure the rolling resistance. If there is a height difference between the rails, moment will act on the LM block. If the LM Guide's groove is the Gothic-arc groove, this will cause spinning. The LM Guide with the circular-arc groove is capable of absorbing the error caused by the height difference between rails as great as 0.3/200 mm, where its rolling resistance will not increase significantly.

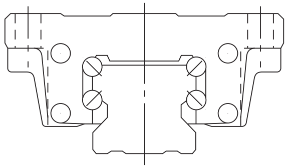


Superb Error-Absorbing Capability with the DF Design

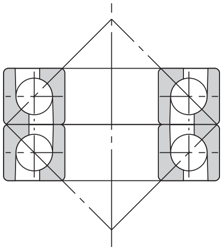
Since the LM Guide has a contact structure similar to the front-to-front mount of angular ball bearings, it has superb self-adjusting capability.



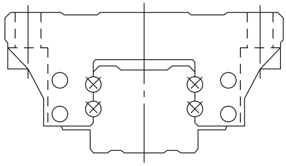
Angular Ball Bearings Mounted Front-to-Front (DF Type)
As the distance ℓ between the application points is small, the allowable tilt angle is large. (Highly self-adjustable)



DF Type Four-Row Angular Contact (LM Guide)
An internal structure that will not be easily affected by inconsistencies on the mounting surface.

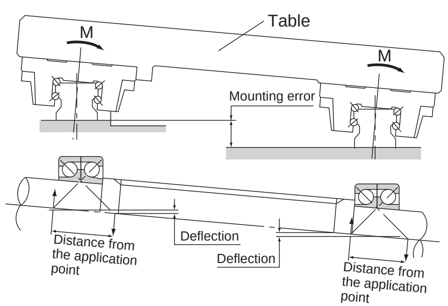
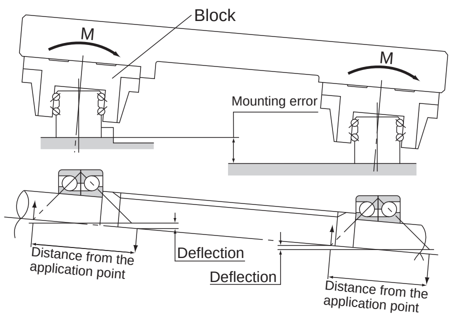


Angular Ball Bearings Mounted Back-to-Back (DB Type)
As the distance between the application points is large, the allowable tilt angle is small.



Four-Row Gothic-Arch Contact
Requires a high mounting precision.

An LM ball guide mounted on a plane receives a moment (M) due to an error in flatness or in level or a deflection of the table. Therefore, it is essential for the guide to have self-adjusting capability.

LM Guide Model HSR	Similar Product of a Competitor
	
Since the distance between the application points of the bearings is small, the internal load generated from inconsistencies in the mounting surface is small, allowing movement to remain smooth.	Since the distance from the application point of the bearing is large, the internal load generated from a mounting error is large and the self-adjusting capability is small. With an LM ball guide having angular ball bearings mounted back-to-back, if there is an error in flatness or a deflection in the table, the internal load applied to the block is approx. 6 times greater than that of the front-to-front mount structure and the service life is much shorter. In addition, the fluctuation in sliding resistance is greater.