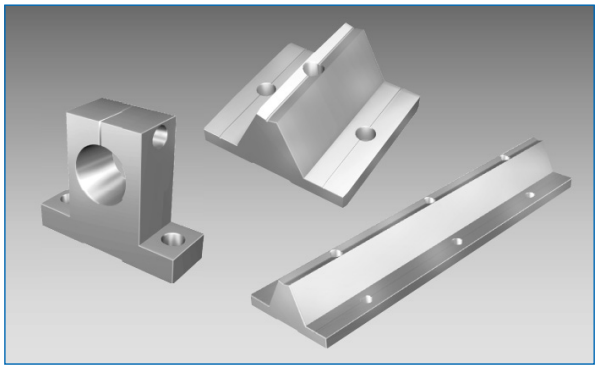
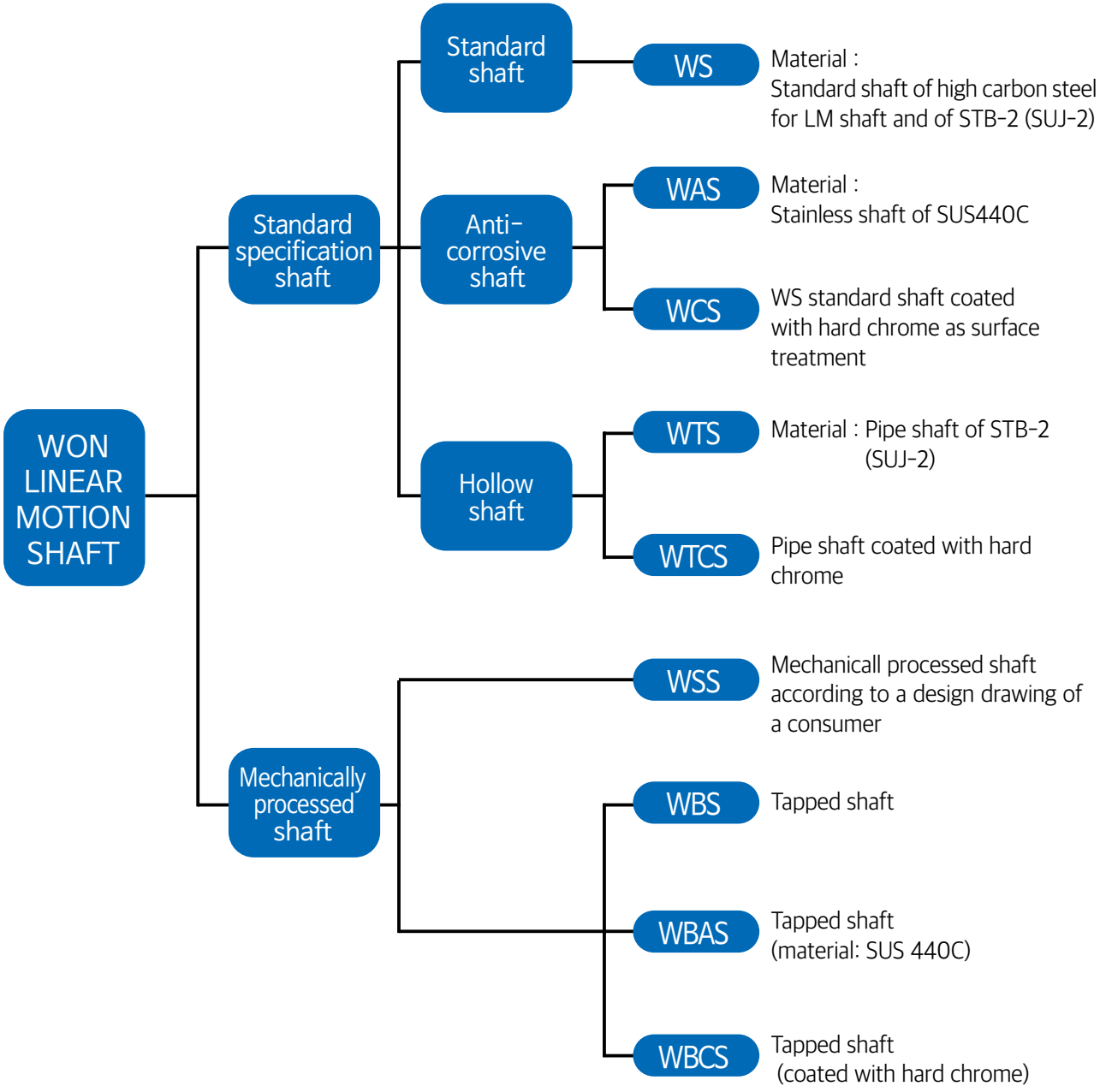
LM Shaft
Contents



1 Linear Motion Shaft

1. Types



WON Linear Motion Shaft for Ball Bushing guides a ball bushing in order to obtain the linear motion with high precision.
A linear motion shaft is used in combination with a ball bushing that has a linear motion. Therefore, the shaft not only guides the ball bushing, but serves as the inner ring of a bearing. The quality of a shaft greatly affects the function of linear motion system as well as a ball bushing.
WON ST selects materials and applies heat treatment, polishing, and mechanical processing in consideration of such a fact, and guarantees the function of WON Linear Motion Shaft through its long-accumulated technologies

2. Materials

- High carbon steel for linear motion shaft (WON ST standard material)
- High carbon chrome bearing steel (KS: STB-2, JIS: SUJ-2)
- Martensitic stainless steel (SUS440C)
  Generally, High carbon chrome bearing steel (STB-2) is used. If corrosive resistance or no lubrication (e.g., chemical & food product machine, medical equipment, semiconductor equipment) is needed, SUS440C is mostly applied.
- Other materials (not for ball bushing)
  -S45C -SUS 303 -SUS 304 -SUS 316

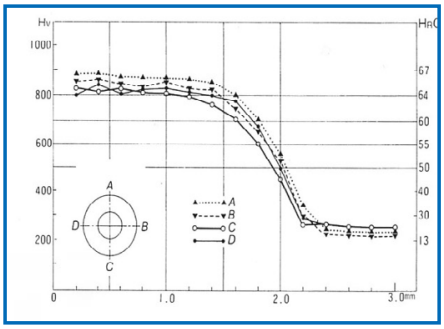
2 Heat Treatment

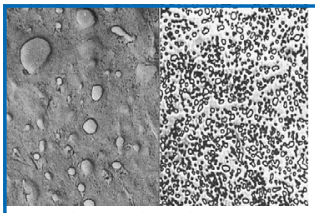
The linear motion shaft heat treatment equipment of WON ST is capable of performing heat treatment with accurate and stable high frequency. Based on the material screened without decarbonized layer, scratches, and cracks, high-frequency heat treatment is applied appropriately depending on a size of a shaft. Tempering is applied to make hardness and the depth of hardened layer uniform according to the length direction and circumferential direction of a shaft.

- Surface hardness

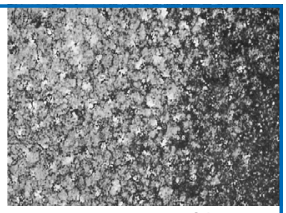
STB-2	over HRC58
SUS440C	HRC56 with over ø 16mm HRC54 with below ø 13mm

Hardness distribution curve ▶
(ø20)





Spheroidized tissue



Cross section of heat treatment with high frequency

Figure 1. Photo of tissue

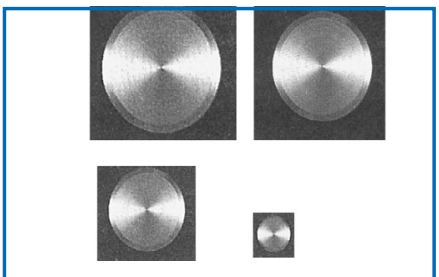
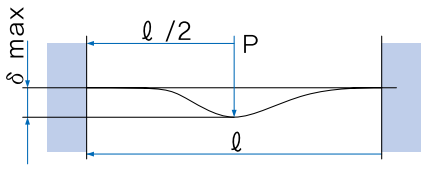
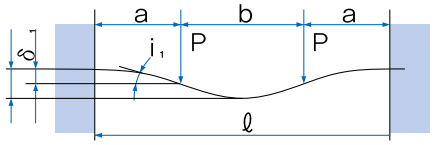
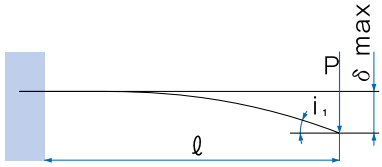


Figure 2. Photo of hardened layer

3 Precision

Tolerance of outside diameter	Surface roughness	Straightness
g6, h6, and h5 shafts are mainly manufactured.	1.5 ㎛ Rmax or less	20㎛ / 300mm or less

4 Calculation of the bending angle of shaft

Support method	Service conditions	Formula to calculate a bending angle	Formula to calculate a bending angle
Fixture of both ends		$\delta max = \frac{P\ell^3}{192EI} = \frac{1}{4} \times P\ell^3 C$	$i_1 = 0$ $i_2 = 0$
Fixture of both ends		$\delta_1 = \frac{Pa^3}{6EI}(2-\frac{3a}{\ell}) = 8Pa^3(2\frac{3a}{\ell})C$ $\delta max = \frac{Pa^3}{24EI}(2+\frac{3b}{a}) = 2Pa^3(2+\frac{3b}{a})C$	$i_1 = \frac{Pa^2b}{2EI \cdot \ell} = \frac{24Pa^2bc}{\ell}$ $i_2 = 0$
Fixture of one end		$\delta max = \frac{P\ell^3}{3EI} = 16P\ell^3 C$	$i_1 = \frac{P\ell^2}{2EI} = 24P\ell^2 c$ $i_2 = 0$

δ_1 : A bending angle at load point (mm)
i_2 : A load angle at support point
I : 2nd moment of cross section (mm^4)
a, b : Distance between load points
P : Intensive load (N)

δmax : Max. bending angle (mm)
E : Modulus of elasticity 2.06^5X10N/mm^2
i_1 : A bending angle at load point
ℓ : Length (mm)
C : 1/48EI(1/kgf · $mm)^2$

1. Solid shaft

$$\text{2nd moment of cross section } (I) = \frac{\pi D^4}{64} \ (mm^4)$$

D = Outside diameter (mm)

The 2nd moment of the cross section of a shaft and the value of C (=1/48EI) are presented below.

Outside diameter	2nd moment of cross section I (mm^4)	C=1/48EI ($1/N \cdot mm^2$)
3	3.98	2.49×10^{-8}
4	1.26×10	7.87×10^{-9}
5	3.07×10	3.23×10^{-9}
6	6.36×10	1.56×10^{-9}
8	2.01×10^{2}	4.94×10^{-10}
10	4.91×10^{2}	2.02×10^{-10}
12	1.02×10^{3}	9.73×10^{-11}
13	1.40×10^{3}	7.09×10^{-11}
15	2.49×10^{3}	3.98×10^{-11}
16	3.22×10^{3}	3.08×10^{-11}
20	7.85×10^{3}	1.26×10^{-11}
25	1.92×10^{4}	5.17×10^{-12}
30	3.98×10^{4}	2.49×10^{-13}
35	7.37×10^{4}	1.35×10^{-13}
40	1.26×10^{5}	7.87×10^{-13}
50	3.07×10^{5}	3.23×10^{-13}
60	6.36×10^{5}	1.56×10^{-13}
80	2.01×10^{6}	4.94×10^{-14}
100	4.91×10^{6}	2.02×10^{-14}
120	1.02×10^{7}	9.73×10^{-15}
150	2.49×10^{7}	3.98×10^{-15}

● An example of calculation

-In the conditions where the outside diameter is 2.5mm, the length of a shaft is 430mm, and the intensive load on the center of the shaft is 784N, the maximum bending value is calculated as follows: (In this case, ignore empty weight of a shaft.)

if) If both ends are fixed,
substitute P=784 (N), ℓ=430 (㎜), and C=5.17 x 10 (1/kgf · ㎟) (the value of the outside diameter 25mm in the above table) in the formula of bending.

$$\delta max = \frac{1}{4} P\ell^3 C = 0.08 \ (mm)$$

2. Hollow shaft

$$\text{2nd moment of cross section } (I) = \frac{\pi}{64} \times (d_2^4 - d_1^4) \ (mm^4)$$

d_2 = Outside diameter (mm), d_1 = Inside diameter (mm)

Outside diameter d_2 (mm)	Inside diameter d_1 (mm)	2nd moment of cross section I (mm^4)	C=1 / 48EI ($1/N \cdot mm^4$)
10	4	4.78×10^{2}	2.08×10^{-10}
13	6	1.34×10^{3}	7.40×10^{-11}
16	8	3.01×10^{3}	3.30×10^{-11}
20	14	5.97×10^{3}	1.66×10^{-11}
25	16	1.60×10^{4}	6.20×10^{-12}
30	17	3.57×10^{4}	2.78×10^{-12}
35	19	6.73×10^{4}	1.47×10^{-12}
40	20	1.18×10^{5}	8.41×10^{-13}
50	25	2.88×10^{5}	3.44×10^{-13}
60	30	5.96×10^{5}	1.66×10^{-13}
80	40	1.88×10^{6}	5.28×10^{-14}
100	50	4.60×10^{6}	2.16×10^{-14}

● An example of calculation

-In the conditions where the outside diameter is 50mm, the inside diameter is 25mm, the length of a hollow shaft is 1800mm, and the intensive load on the center of the shaft is 784N, the maximum bending value based on an empty weight is calculated as follows: (See the next page.)

if) If both ends are fixed,
substitute P=100, ℓ=1800 (㎜),
and C = 3.44 x 10^{-13} (1/N . mm^2)
(in the table) in the formula of bending.

$$\delta \max = \frac{1}{4} P\ell^3 C = 0.05 \ (㎜)$$

5 Composition of model name & number

1. Model number format I (solid shaft)

WS – D 16 h6 x 2000
① ② ③ ④ ⑤

① Symbol of shaft model number

Solid shaft	WS	This model is the ball bushing shaft most used. · Material: high carbon steel for linear motion shaft (S55C), STB-2(SUJ-2)
	WAS	This model as a shaft for ball bushing is excellent at corrosive resistance, and is suitable for an environment with easy corrosion, an oxidative environment with no use of lubricants, and cleanroom. · Material: SUS440C
	WCS	The surface of this model is treated with hard chrome plating. It is suitable and economic for an easy-to-rust environment or poor environment. · Material: high carbon steel for linear motion shaft (S55C), STB-2(SUJ-2)

② Symbol of mechanical processing (No description means a standard product or a simple cut product.)

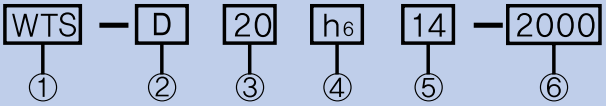
D	Processed in reference to a drawing

③ Outside diameter (㎜), ④ Allowable tolerance of outside diameter (㎛), ⑤ Length (㎜)

Outside diameter (㎜)	Allowable tolerance of outside diameter (㎛)			Standard length in stock L (mm)						
	g6	h5	h6	300	500	1000	1200	1500	2000	3000
3	−2 ~ −8	0 ~ −4	0 ~ −6							
4	−4 ~ −12	0 ~ −5	0 ~ −8							
5										
6										
8	−5 ~ −14	0 ~ −6	0 ~ −9							
10										
12	−6 ~ −17	0 ~ −8	0 ~ −11							
13										
16										
20	−7 ~ −20	0 ~ −9	0 ~ −13							
25										
30										
35	−9 ~ −25	0 ~ −11	0 ~ −16							
40										
50										
60	−10 ~ −29	0 ~ −13	0 ~ −19							
80										

Note 1. For any question about the maximum length, please contact us.
2. The available maximum dimension of outside diameter is ø300.

2. Model number format II (Hollow shaft)



① Symbol of shaft model number

hollow shaft	WTS	This model helps to make equipment and machine lightweight, and to lessen greatly inertial force if a shaft has a linear motion. In addition, an internal bore can be used for wiring or piping. · Material: high carbon steel for linear motion shaft (S55C), STB-2(SUJ-2)
	WTCS	This model is the ball bushing shaft plated with hard chrome in order to prevent corrosion in the outside diameter. · Material: high carbon steel for linear motion shaft (S55C), STB-2(SUJ-2)
	WTAS	This model is the stainless shaft with a bore. It has the advantages of both WAS and WTS. · Material: SUS440C

② Symbol of mechanical processing (No description means a standard product or a simple cut product.)

D	Processed in reference to a drawing

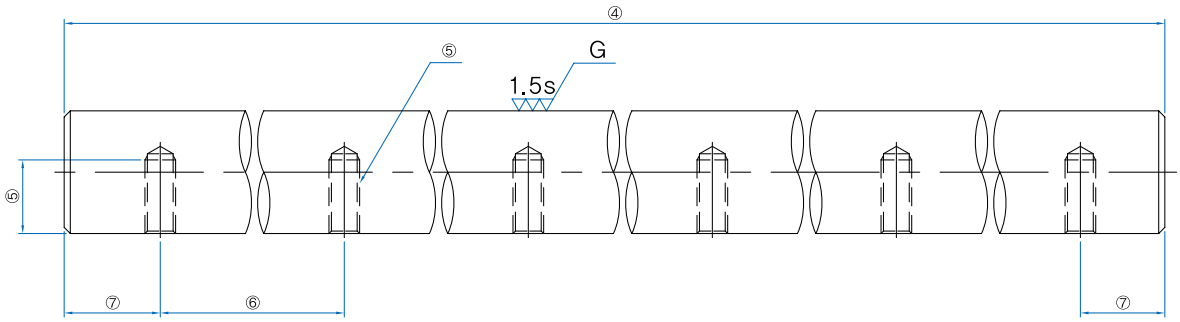
③ Outside diameter (㎜), ④ Allowable tolerance of outside diameter (㎛), ⑤ Inside diameter (㎜), ⑥ Length (㎜)

Outside diameter (㎜)	Inside diameter (㎜)	Allowable tolerance of outside diameter (㎛)			Standard length in stock L (mm)
		g6	h5	h6	
10	4	-5~-14	0~-6	0~-9	1000, 1200, 1500, 2000, 3000
12	6	-6~-17	0~8	0~-11	
16	8				
20	14	-7~-20	0~-9	0~-13	
25	16				
30	17				
35	19	-9~-25	0~-11	0~-16	
40	20				
50	25				

Note : Hollow shafts with different specifications can be manufactured.

3. Model number format Ⅲ (Tapped shaft)

WBS – 16 h6 × 2000 – M5 × 200 – 100
① ② ③ ④ ⑤ ⑥ ⑦



① Symbol of shaft model number

Line tapped shaft	WBS	General line tapped shaft · Material : high carbon steel for linear motion shaft (S55C), STB-2(SUJ-2)	This device is used together with a shaft line support. It is mostly applied to an environment where shaft bending or vibration occurs
	WBAS	Stainless line tapped shaft with corrosive resistance · Material : SUS440C	
	WBCS	Anti-corrosive line tapped shaft plated with hard Cr · Material : high carbon steel for linear motion shaft (S55C), STB-2(SUJ-2)	

② Outside diameter (㎜), ③ Allowable tolerance of outside diameter (㎛), ④ Length (㎜), ⑤ Tap size (㎜), ⑥ Tap distance (㎜), ⑦ Distance between both ends (㎜) / Standard length in stock

Outside diameter	Allowable tolerance of outside diameter (㎛)			Standard length in stock L (mm)					Tap size	Tap distance	Distance between both ends
D(㎜)	g6	h5	h6	1000	1200	1500	2000	3000		(㎜)	(㎜)
10	−5～−14	0～−6	0～−9						M4 x 0.7 x 6	100	50
12	−6～−17	0～−8	0～−11						M4 x 0.7 x 6	100	50
13									M4 x 0.7 x 6	100	50

Outside diameter	Allowable tolerance of outside diameter (μm)			Standard length in stock L (mm)					Tap size	Tap distance	Distance between both ends
D(mm)	g6	h5	h6	1000	1200	1500	2000	3000		(mm)	(mm)
16	−7~−20	0~−9	0~−13						M5x0.8x9	150	75
20									M6x1x10	150	75
25									M6x1x12	200	100
30									M8x1.25x15	200	100
35	−9~−25	0~−11	0~−16						M8x1.25x15	200	100
40									M8x1.25x18	300	150
50									M10x1.5x22	300	150

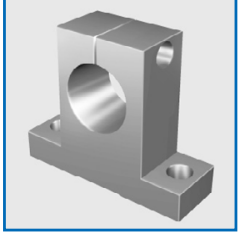
Note : For any question about the maximum length, please contact us.

6 Shaft Supports

1. Shaft end support

It helps to support the both ends of a linear motion shaft for ball bushing without any special processing. There is a model for a plane.

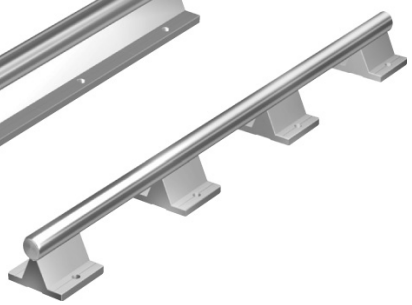
For a plane



2. Shaft line support

It helps to support a line tapped shaft in an environment where there is any concern about ball shaft bending or vibration. Together with an open-type ball bushing, it is used to make a slide rail unit.

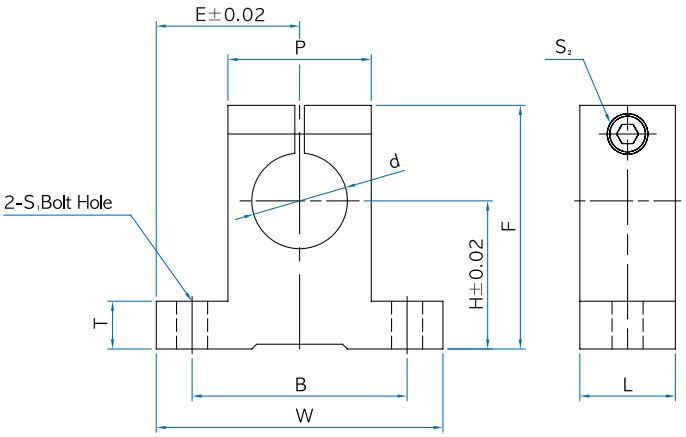
ST Series Shaft Line Support I

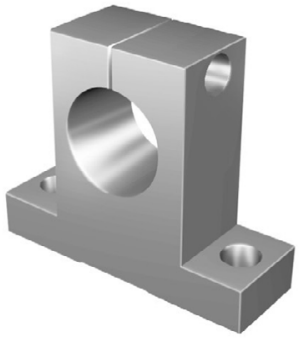


STU Series Shaft Line Support II

WK Type

Shaft end support for a plane





Unit : mm

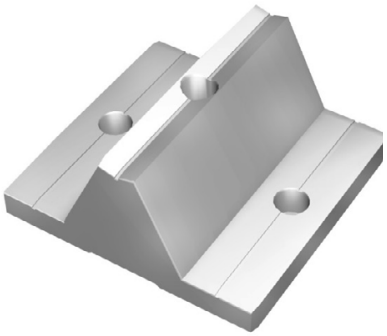
Model No.	Diameter of shaft d	Main dimensions								Mounting bolt spec S_1	Fastening bolt spec S_2
		H	E	W	L	F	T	P	B		
WK 10	Ø10	20	21	42	14	32.8	6	18	32	M5	M4
WK 12	Ø12	23	21	42	14	38	6	20	32	M5	M4
WK 13	Ø13	23	21	42	14	38	6	20	32	M5	M4
WK 16	Ø16	27	24	48	16	44	8	25	38	M5	M4
WK 20	Ø20	31	30	60	20	51	10	30	45	M6	M5
WK 25	Ø25	35	35	70	24	60	12	38	56	M6	M6
WK 30	Ø30	42	42	84	28	70	12	44	64	M8	M6
WK 35	Ø35	50	49	98	32	82	15	50	74	M10	M8
WK 40	Ø40	60	57	114	36	96	15	60	90	M10	M8

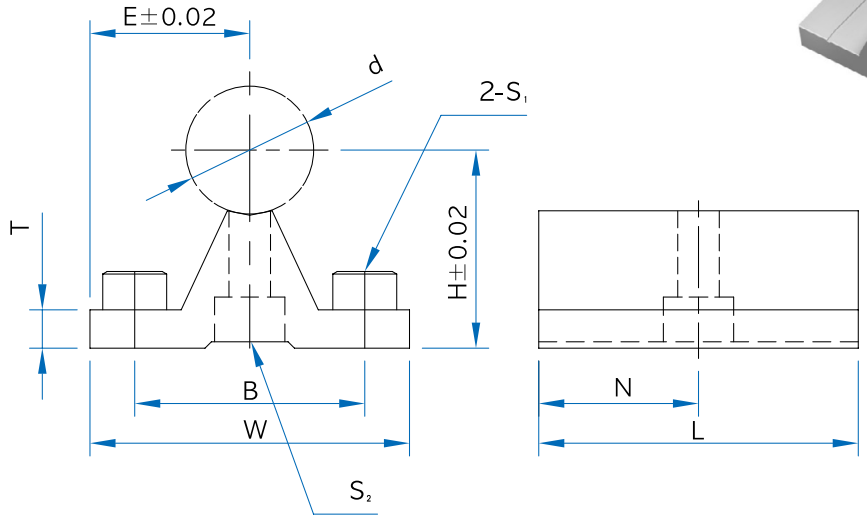
● Material : Aluminum AL6061

S-ST Type

Shaft line support I

Applied ball bushing block SHO





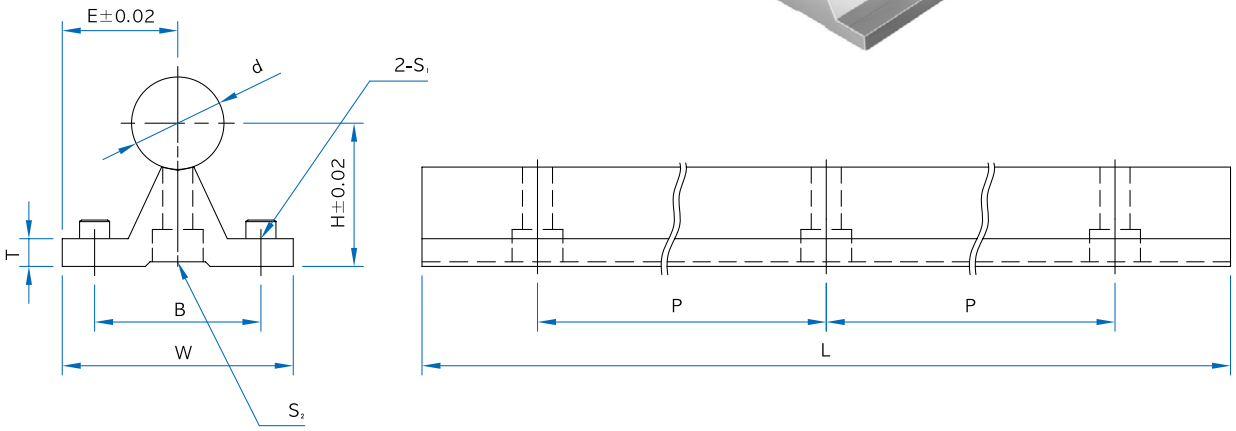
Unit : mm

Model No.	Diameter of shaft d	Main dimensions					Mounting dimensions			
		H	E	W	L	T	B	N	S_1	S_2
S-ST16×50	Ø16	25	20	40	50	5	30	25	M5	M5
S-ST20×50	Ø20	27	22.5	45	50	5	30	25	M5	M6
S-ST25×50	Ø25	33	27.5	55	50	6	35	25	M6	M6
S-ST30×60	Ø30	37	30	60	60	7	40	30	M6	M8
S-ST40×70	Ø40	48	37.5	75	70	9	55	35	M8	M8

ST Type

Shaft line support I

Applied ball bushing block SHO



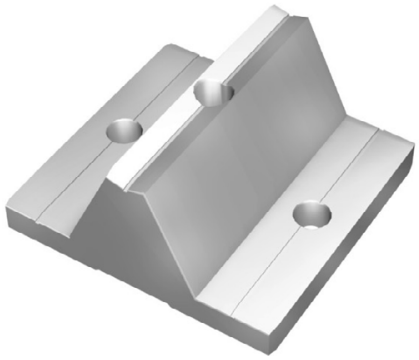
Unit : mm

Model No.	Diameter of shaft d	Main dimensions					Mounting dimensions			
		H	E	W	L	T	B	P※	S_1	S_2
ST 16	Ø16	25	20	40	Max. length 3m · Linking multiple supports is available	5	30	150	M5	M5
ST 20	Ø20	27	22.5	45		5	30	150	M5	M6
ST 25	Ø25	33	27.5	55		6	35	200	M6	M6
ST 30	Ø30	37	30	60		7	40	200	M6	M8
ST 40	Ø40	48	37.5	75		9	55	300	M8	M8

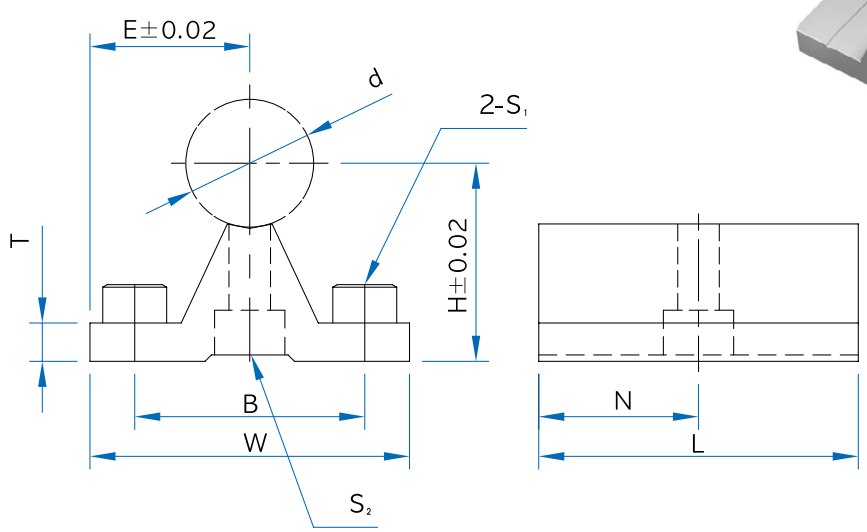
Note: P* dimensions can be changed at a customer request.

S-STU Type

Shaft line support II



Applied ball bushing block SHO , CSO



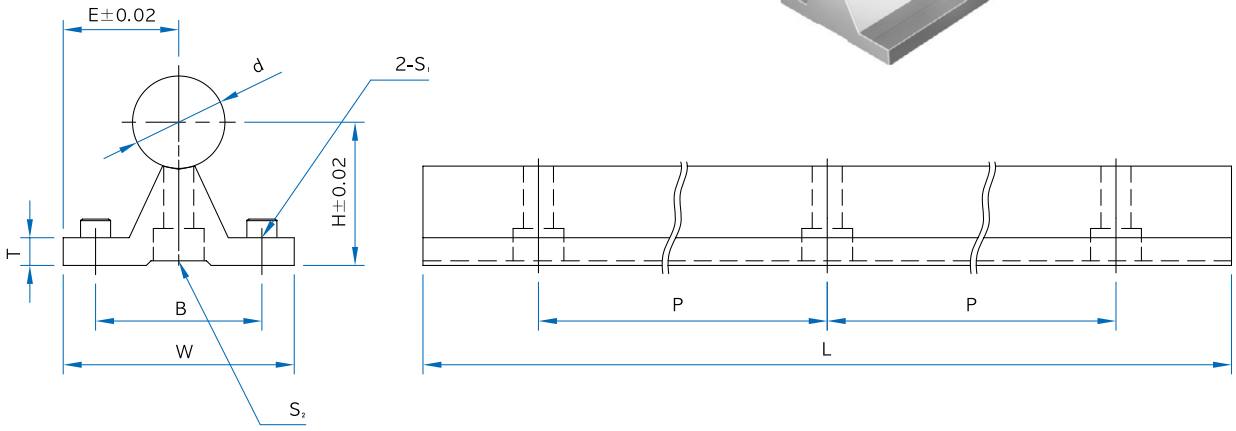
Unit : mm

Model No.	Diameter of shaft d	Main dimensions					Mounting dimensions			
		H	E	W	L	T	B	N	S_1	S_2
S-STU16x50	ø16	27	21	42	50	6	31	25	M5	M5
S-STU20x50	ø20	31	25	50	50	6	36	25	M6	M6
S-STU25x50	ø25	36	26.5	53	50	7	39	25	M6	M6
S-STU30x60	ø30	43	33.5	67	60	8	49	30	M8	M8
S-STU40x70	ø40	55	37	74	70	11	56	35	M8	M8

STU Type

Shaft line support II

Applied ball bushing block SHO , CSO



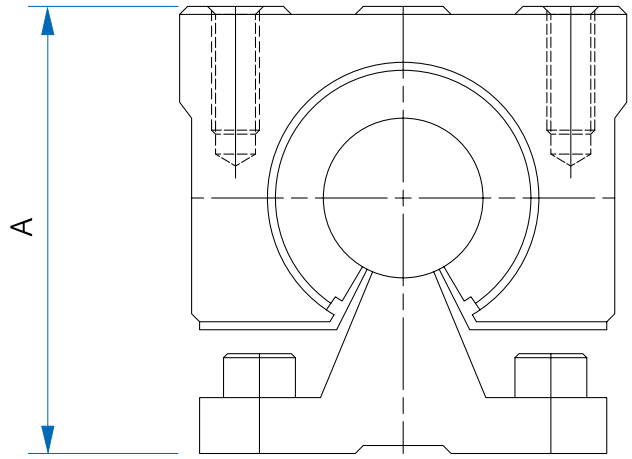
Unit : mm

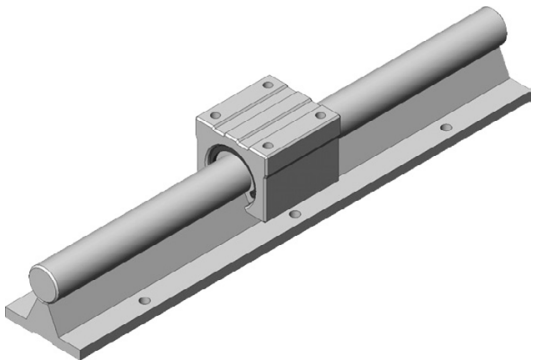
Model No.	Diameter of shaft d	Main dimensions					Mounting dimensions			
		H	E	W	L	T	B	P※	S_1	S_2
STU16	Ø16	27	21	42	Max. length 3m · Linking multiple supports is available	6	31	150	M5	M5
STU20	Ø20	31	25	50		6	36	150	M6	M6
STU25	Ø25	36	26.5	53		7	39	200	M6	M6
STU30	Ø30	43	33.5	67		8	49	200	M8	M8
STU40	Ø40	55	37	74		11	56	300	M8	M8

Note: P* dimensions can be changed at a customer request.

Slide Rail Unit

A slide rail unit is composed of an open-type block, a line tapped shaft, and a shaft line support.





Assembly height A

Diameter of shaft	Shaft line support / Open-type block	S–ST ST	S–STU STU
16	SHO 16 UU	45	47
	CSO 16 UU		49
20	SHO 20 UU	50	54
	CSO 20 UU		56
25	SHO 25 UU	60	63
	CSO 25 UU		66
30	SHO 30 UU	70	76
	CSO 30 UU		78
40	SHO 40 UU	90	97
	CSO 40 UU		100