

B-3-1.9 Σ Series for Robot

1. Features

Σ Series (NSK's Robotte) is a ball screw with a high-performance spline. It is ideal for various actuators such as the vertical axis of SCALA type robot.

A ball screw groove and a ball spline groove are made in one shaft, combining the ball screw and the ball spline.

Mount housing, nuts, and support bearings are combined into a single unit.

Timing pulley (prepared by the user) is directly secured at the end face of the nut.

● High functions

A single shaft has both feeding mechanism and guide functions. This allows the shaft ends to move back and forth (linear motion), as well as to rotate.

● Compact and lightweight

A ball screw nut and a spline nut are placed on one shaft, and a support bearings are also combined to the unit. This allows compact and high-precision design. Hollow shaft is standard to reduce weight. The hollow can be used for wiring and piping. Other components are also designed to be light in weight.

● Low inertia

Because of return tube type ball nut of which outside diameter is decreased, low inertia design is enabled.

It reduces the inertia by 19% of conventional products.

2. Functions

As shown in Fig. 1, the ball screw nut and a spline nut are rotated independently to control rotation value. Thereby the shaft can move in any direction -- linear and rotational. Table 1 shows the relationship between power input and output.

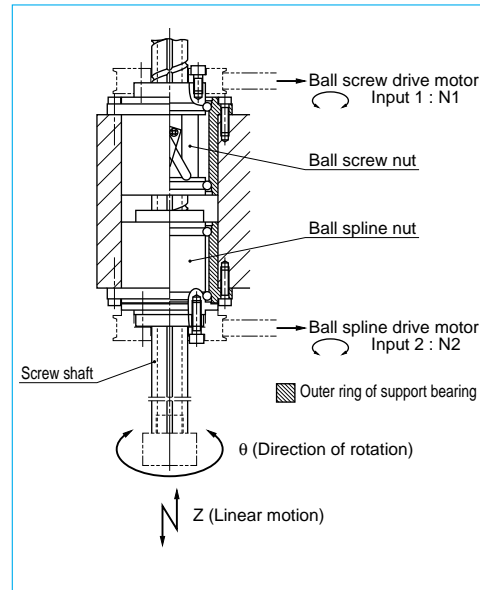


Fig. 1 Example structure of Z axis plus θ axis actuator

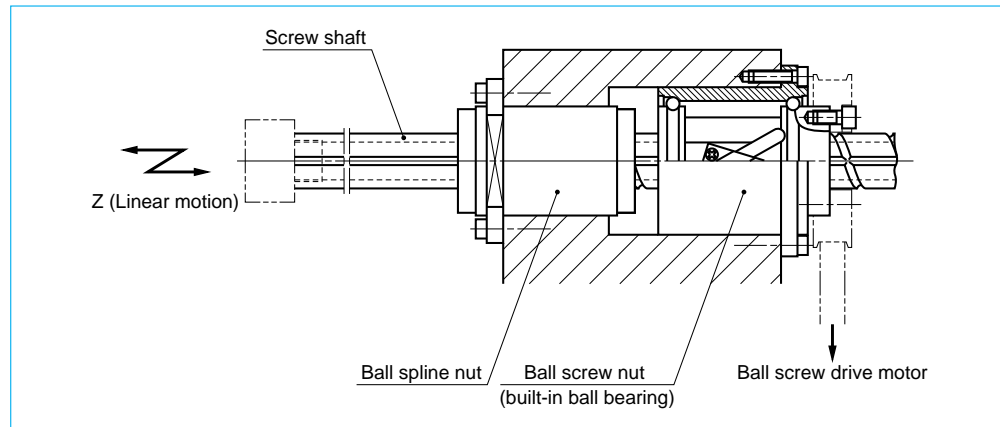


Fig. 2 Example structure of single Z axis unit

Table 1 Power input and output of Σ Series

Shaft movement (output)		Input		Remarks
Z (Up-down movement) (mm/min)	θ (Rotational movement) (min^{-1})	① Ball screw (min^{-1})	② Spline (min^{-1})	
Up, down $N1 \times l$	Stop 0	Rotate N1	Stop 0	-
Stop 0	Rotate N2	Rotate N1	Rotate N2	$N1 = N2$
Up, down $N2 \times l$	Rotate N2	Stop 0	Rotate N2	-
Up, down $N1-N2 \times l$	Rotate N2	Rotate N1	Rotate N2	$N1 \neq N2$

3. Specifications

(1) Recirculation system

A structure of return tube recirculation system is shown below.

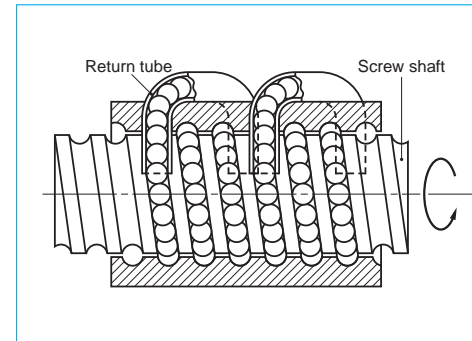


Fig. 3 Structure of return tube recirculation system

(2) Accuracy grade and axial play

The available standard accuracy grade and axial play for ball screw are as follows. The axial play for spline is 0 mm (preloaded product). Please consult NSK for other grades.

Table 2 Accuracy grade and axial play

Accuracy grade	C3, C5, Ct7
Axial play	Z, 0 mm (Preloaded) T, 0.005 mm or less; S, 0.020 mm or less

(3) Allowable $d \cdot n$ value and the criterion of maximum rotational speed

Allowable $d \cdot n$ value and the criterion of maximum rotational speed are shown below. Please consult NSK if the rotational speed exceeds the permissible range below.

Permissible $d \cdot n$ value: 70000 or less

Criterion of maximum rotational speed: 3000 min^{-1}

Note: Please also review the critical speed.

For details, see "Technical Description: Permissible rotational speed" (Page B51).

(4) Application

SCALA type and Cartesian type industrial robots, semiconductor manufacturing machines, machines for automobile production facilities, material handling systems, other Z (vertical) axis and Z axis plus θ (rotation) axis actuators.

4. Design precautions

The overall length L can be extended to 25 times of the shaft diameter.

To remove the spline nut from the shaft for assembling, use an arbor as shown in Fig. 4. Avoid removing ball screw nut as much as possible. Refer to root diameter in the dimension table for arbor diameter. (NSK manufactures the arbors on request.)

For general precautions regarding ball screws, refer to "Precautions in Designing" (Page B84) and "Precautions in Handling" (Page B103).

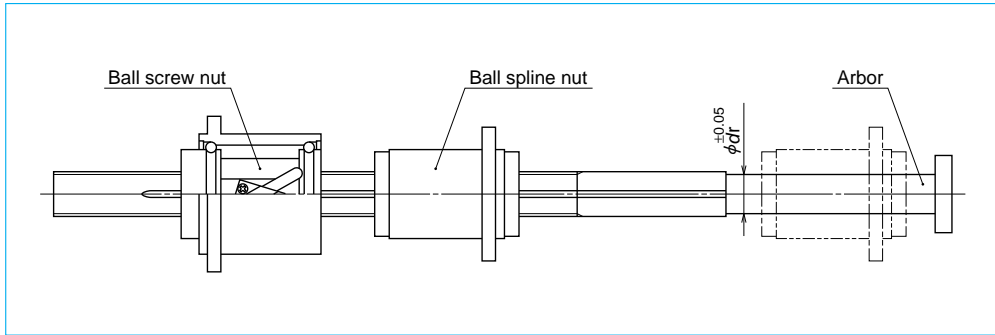


Fig. 4 Removing spline nut

5. Product categories

Σ Series (NSK's Robotte) is four models with different moving functions and performances are available. Select a standard model if rigidity is important. A compact system is recommended for reducing the weight of machine.

Table 3 Σ Series product categories

Model	Appearance	Size	Structure (Movement)
Σ		Standard	Z+ θ Unit
ΣZ		Standard	Z Unit
ΣC		Compact	Z+ θ Unit
ΣCZ		Compact	Z Unit

6. Load rating and life

The relationship between load rating of the ball spline section and life is the same as in other NSK liner motion products. However, various loads that apply to Robotte must be taken into account. For example, the following factors must be considered in calculating life when the product is used as shown in Fig. 5.

- Fa : Load that is generated when the shaft moves in up-down direction. (Load is applied to the ball screw nut.)
- T : Torque that is generated to the shaft by Fa.
- Fr : Load that is generated by moment of inertia of the shaft and the work attached to Robotte as well as by centrifugal force when the arm rotates.
- θ : Direction of Fr load that changes by shaft rotation.

NSK has life calculation programs which take these factors into account. Please ask NSK for more details.

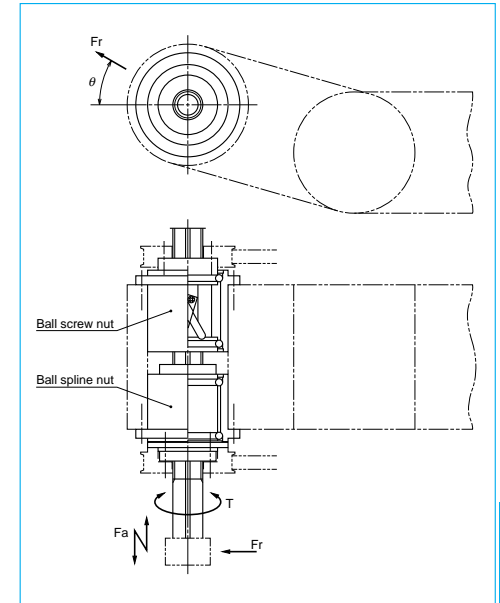


Fig. 5 Example structure of Z axis plus θ axis actuator

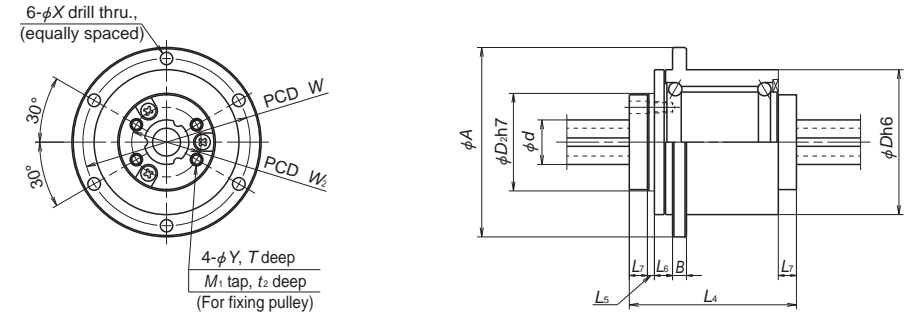
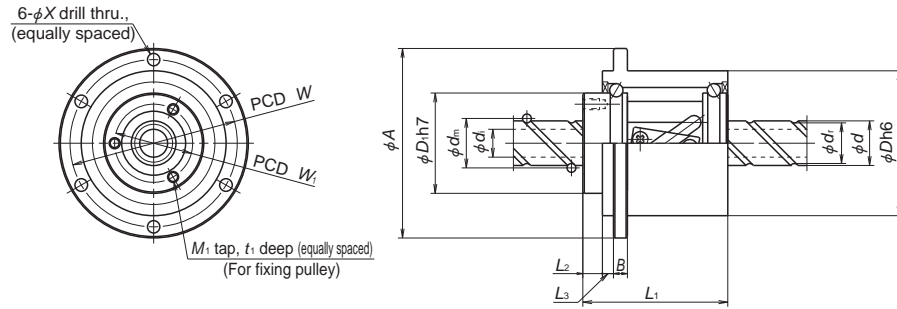
7. Example of model number in dimension table

A structure of "Reference number for ball screw" is as follows.

◇Reference number for ball screw

PW 25 02 - ** P T U - C5 Z 20

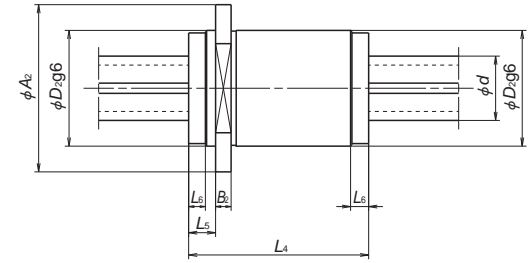
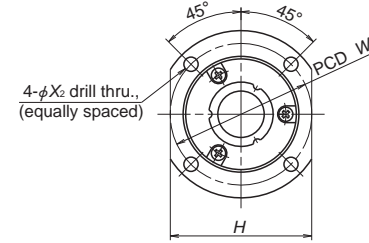
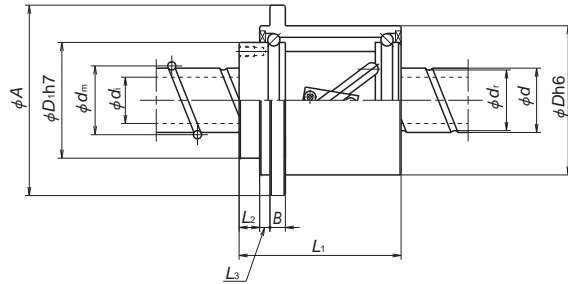
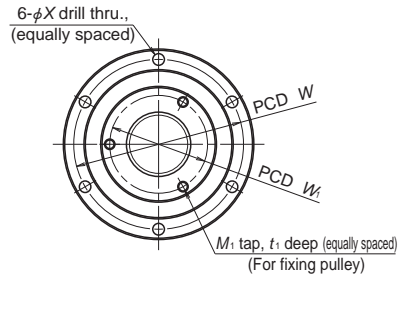
Product code	Screw shaft diameter (mm)	Effective threaded length (unit in 100 mm)	Design serial number	Preload code: No code ; Non-preload	Lead (mm)	Axial play code: Z, T, S	Accuracy grade: C3, C5, C7 (Ct7)	Use support unit	Hollow shaft ball screw specification
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Unit: mm

Model No.	Shaft dia. <i>d</i>	Lead <i>l</i>	Ball dia. <i>D_w</i>	Ball circle dia. <i>d_m</i>	Root dia. <i>d_r</i>	Screw shaft hollow <i>d_i</i>	Ball screw nut															Moment of inertia (kg·cm ²)
							Basic load rating (N)		Dimensions													
							Dynamic <i>C_a</i>	Static <i>C_{0a}</i>	<i>D</i>	<i>A</i>	<i>B</i>	<i>L₁</i>	<i>L₂</i>	<i>L₃</i>	<i>M₁</i>	<i>t₁</i>	<i>W₁</i>	<i>D₁</i>	<i>W</i>	<i>X</i>		
Σ1610	16	10	3.175	16.75	13.4	(8)	4710	8110	48	64	5	47	7	4	3-M4	6	28	35	56	4.5	0.41	
Σ1632	16	32	3.175	16.75	13.4	(8)	2990	4870	48	64	5	52	7	4	3-M4	6	28	35	56	4.5	0.44	
Σ2010	20	10	3.175	20.75	17.4	(14)	8210	17500	54	70	6	57	8	4	3-M4	6	32	40	62	4.5	0.64	
Σ2020	20	20	3.175	20.75	17.4	(14)	5290	10300	54	70	6	63	8	4	3-M4	6	32	40	62	4.5	0.65	
Σ2040	20	40	3.175	20.75	17.4	(14)	3360	6170	54	70	6	57	8	4	3-M4	6	32	40	62	4.5	0.64	
Σ2510	25	10	3.175	25.75	22.4	(18)	9110	21900	58	74	6	57	8	4	3-M4	6	38	45	66	4.5	1.10	
Σ2520	25	20	3.175	25.75	22.4	(18)	5870	13200	58	74	6	63	8	4	3-M4	6	38	45	66	4.5	1.18	
Σ2525	25	25	3.175	25.75	22.4	(18)	5870	13200	58	74	6	72	8	4	3-M4	6	38	45	66	4.5	1.30	
Σ3220	32	20	3.175	32.75	29.4	(25)	6540	16800	70	95	8	70	10	6	3-M5	10	44	53	82	6.6	2.60	
Σ3232	32	32	3.175	32.75	29.4	(25)	6540	16800	70	95	8	91	10	6	3-M5	10	44	53	82	6.6	3.15	
Σ4020	40	20	3.969	41.0	36.9	(30)	9770	26300	85	110	8	73	10	6	4-M5	10	58	67	96	6.6	5.96	
Σ4040	40	40	3.969	41.0	36.9	(30)	9770	26300	85	110	8	107	10	6	4-M5	10	58	67	96	6.6	7.85	
Σ4520	45	20	3.969	46.0	41.9	(35)	10300	29700	90	115	8	73	10	6	4-M5	10	63	72	101	6.6	7.73	
Σ4540	45	40	3.969	46.0	41.9	(35)	10300	29700	90	115	8	107	10	6	4-M5	10	63	72	101	6.6	10.3	

Mass (kg)	Ball spline nut																			Moment of inertia (kg·cm ²)	Mass (kg)
	Basic load rating (N)		Basic torque (N·m)		Dimensions																
	Dynamic <i>C_r</i>	Static <i>C_{0r}</i>	Dynamic <i>C_t</i>	Static <i>C_{0t}</i>	<i>D</i>	<i>A</i>	<i>B</i>	<i>L₄</i>	<i>L₅</i>	<i>L₆</i>	<i>L₇</i>	<i>Y</i>	<i>T</i>	<i>M₂</i>	<i>t₂</i>	<i>W₂</i>	<i>D₂</i>	<i>W</i>	<i>X</i>		
0.50	5530	7270	61.5	91.3	48	64	5	60	2.5	6.5	6.5	4.5	6.5	M4	7	25	35	56	4.5	0.71	0.63
0.55	5890	8000	65.5	100	48	64	5	60	2.5	6.5	6.5	4.5	6.5	M4	7	25	35	56	4.5	0.71	0.63
0.74	6260	8720	86.3	135	54	70	6	65	2.5	6.5	6.5	5.5	6.5	M5	8	30.5	40	62	4.5	1.15	0.87
0.81	6610	9450	91.1	145	54	70	6	65	2.5	6.5	6.5	5.5	6.5	M5	8	30.5	40	62	4.5	1.15	0.87
0.74	6610	9450	91.1	145	54	70	6	65	2.5	6.5	6.5	5.5	6.5	M5	8	30.5	40	62	4.5	1.15	0.87
0.81	6630	9450	115	185	58	74	6	70	2.5	6.5	6.5	5.5	6.5	M5	8	35.5	45	66	4.5	1.88	1.03
0.88	7290	10900	125	210	58	74	6	70	2.5	6.5	6.5	5.5	6.5	M5	8	35.5	45	66	4.5	1.88	1.03
1.00	7290	10900	125	210	58	74	6	70	2.5	6.5	6.5	5.5	6.5	M5	8	35.5	45	66	4.5	1.88	1.03
1.46	7630	11600	165	285	70	95	8	75	2.5	7.5	6.5	5.5	6.5	M5	8	42	50	82	6.6	3.80	1.62
1.83	7950	12400	175	305	70	95	8	75	2.5	7.5	6.5	5.5	6.5	M5	8	42	50	82	6.6	3.80	1.62
2.02	10600	14800	290	455	85	110	8	80	4	7.5	8	5.5	8	M5	8	55	65	96	6.6	9.74	2.38
2.85	11200	15900	305	490	85	110	8	80	4	7.5	8	5.5	8	M5	8	55	65	96	6.6	9.74	2.38
2.17	11200	15900	340	550	90	115	8	85	4	7.5	8	5.5	8	M5	8	60	70	101	6.6	12.5	2.56
3.06	11700	17000	360	590	90	115	8	85	4	7.5	8	5.5	8	M5	8	60	70	101	6.6	12.5	2.56

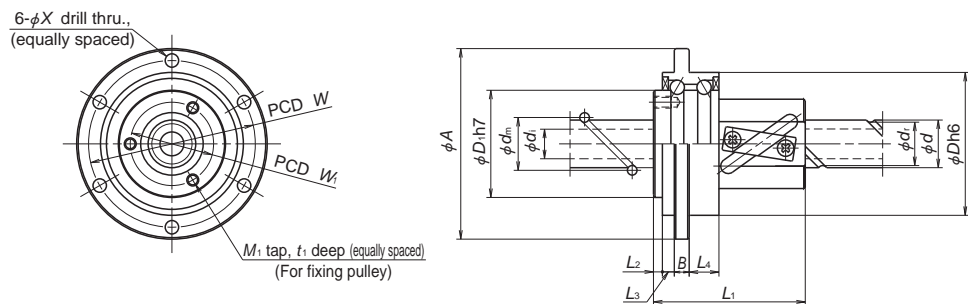


Unit: mm

Model No.	Shaft dia. <i>d</i>	Lead <i>l</i>	Ball dia. <i>D_w</i>	Ball circle dia. <i>d_m</i>	Root dia. <i>d_r</i>	Screw shaft hollow <i>d₁</i>	Ball screw nut													
							Basic load rating (N)		Dimensions											
							Dynamic <i>C_a</i>	Static <i>C_{0a}</i>	<i>D</i>	<i>A</i>	<i>B</i>	<i>L₁</i>	<i>L₂</i>	<i>L₃</i>	<i>M₁</i>	<i>t₁</i>	<i>W₁</i>	<i>D₁</i>	<i>W</i>	<i>X</i>
ΣZ1610	16	10	3.175	16.75	13.4	(8)	4710	8110	48	64	5	47	7	4	3-M4	6	28	35	56	4.5
ΣZ1632		32					2990	4870				52								
ΣZ2010	20	10	3.175	20.75	17.4	(14)	8210	17500	54	70	6	57	8	4	3-M4	6	32	40	62	4.5
ΣZ2020		20					5290	10300				63								
ΣZ2040		40					3360	6170				57								
ΣZ2510	25	10	3.175	25.75	22.4	(18)	9110	21900	58	74	6	57	8	4	3-M4	6	38	45	66	4.5
ΣZ2520		20					5870	13200				63								
ΣZ2525		25					5870	13200				72								
ΣZ3220	32	20	3.175	32.75	29.4	(25)	6540	16800	70	95	8	70	10	6	3-M5	10	44	53	82	6.6
ΣZ3232		32					6540	16800				91								
ΣZ4020	40	20	3.969	41.0	36.9	(30)	9770	26300	85	110	8	73	10	6	4-M5	10	58	67	96	6.6
ΣZ4040		40					9770	26300				107								
ΣZ4520	45	20	3.969	46.0	41.9	(35)	10300	29700	90	115	8	73	10	6	4-M5	10	63	72	101	6.6
ΣZ4540		40					10300	29700				107								

Moment of inertia (kg·cm ²)	Mass (kg)	Ball spline nut																
		Basic load rating (N)		Basic torque (N·m)		Dimensions											Mass (kg)	
		Dynamic <i>C_t</i>	Static <i>C_{0t}</i>	Dynamic <i>C₁</i>	Static <i>C_{0t}</i>	<i>D₂</i>	<i>A₂</i>	<i>B₂</i>	<i>L₄</i>	<i>L₅</i>	<i>L₆</i>	<i>H</i>	<i>W₂</i>	<i>X</i>				
0.41	0.50	5530	7270	61.5	91.3	35	55	6	60	10.5	6.5	4.5	4.5	4.5	0.35			
0.44	0.55	5890	8000	65.5	100	40	60	6	65	10.5	6.5	50	50	5.5	0.46			
0.64	0.74	6260	8720	86.5	135													
0.65	0.81	6610	9450	91.1	145													
0.64	0.74	6610	9450	91.1	145	45	65	6	70	10.5	6.5	55	55	5.5	0.57			
1.10	0.81	6630	9450	115	185													
1.18	0.88	7290	10900	125	210													
1.30	1.00	7290	10900	125	210													
2.60	1.46	7630	11600	165	285	50	70	6	75	10.5	6.5	60	60	5.5	0.64			
3.15	1.83	7950	12400	175	305													
5.96	2.02	10600	14800	290	455	65	88	8	80	12	8	76	76	6.6	1.20			
7.85	2.85	11200	15900	305	490													
7.73	2.17	11200	15900	340	550	70	93	8	85	12	8	81	81	6.6	1.39			
10.3	3.06	11700	17000	360	590													

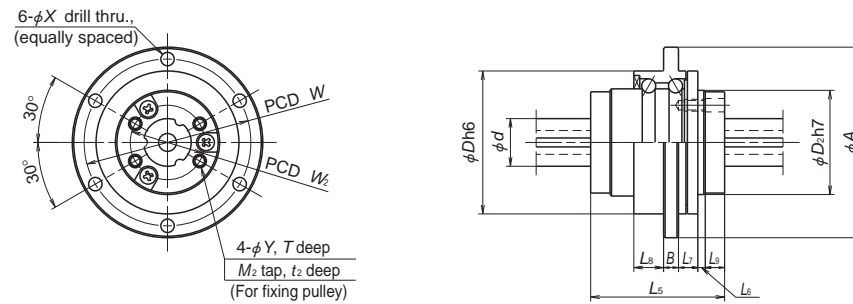
Σ Series for Robotte



Model No.	Shaft dia. <i>d</i>	Lead <i>I</i>	Ball dia. <i>D_w</i>	Ball circle dia. <i>d_m</i>	Root dia. <i>d_r</i>	Screw shaft hollow <i>d_i</i>	Ball screw nut																
							Basic load rating(N)		Dimensions													Moment of inertia (kg·cm ²)	
							Dynamic <i>C_a</i>	Static <i>C_{0a}</i>	<i>D</i>	<i>A</i>	<i>B</i>	<i>L₁</i>	<i>L₂</i>	<i>L₃</i>	<i>L₄</i>	<i>M₁</i>	<i>t₁</i>	<i>W₁</i>	<i>D₁</i>	<i>W</i>	<i>X</i>		
ΣC1610	16	10	3.175	16.75	13.4	(8)	4710	8110	48	64	5	46	3	4	10	3-M4	6	28	35	56	4.5	0.40	
ΣC1632		32					2990	4870				51			10								0.43
ΣC2010	20	10	3.175	20.75	17.4	(14)	8210	17500	54	70	6	56	4	4	10	3-M4	6	32	40	62	4.5	0.63	
ΣC2020		20					5290	10300				63			10								0.65
ΣC2040		40					3360	6170				56			10								0.63
ΣC2510		10					9110	21900				56			10								1.04
ΣC2520	25	20	3.175	25.75	22.4	(18)	5870	13200	58	74	6	63	4	4	10	3-M4	6	38	45	66	4.5	1.13	
ΣC2525		25					5870	13200				71			10								1.24

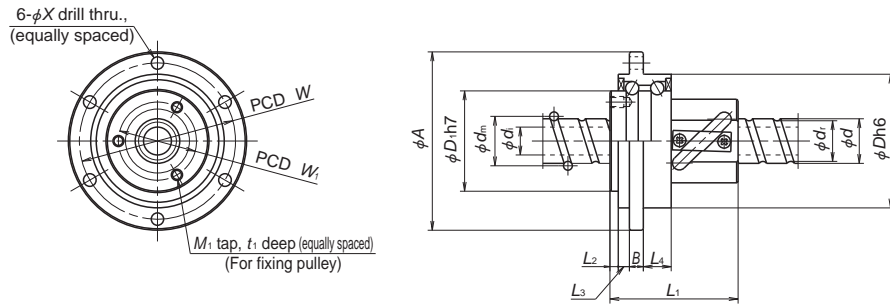
Σ C Type

NSK

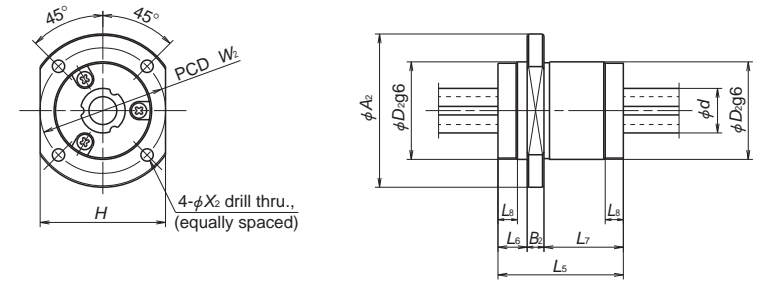


Model No.	Shaft dia. <i>d</i>	Lead <i>I</i>	Ball dia. <i>D_w</i>	Ball circle dia. <i>d_m</i>	Root dia. <i>d_r</i>	Screw shaft hollow <i>d_i</i>	Ball spline nut																						
							Basic load rating(N)		Dimensions													Moment of inertia (kg·cm ²)	Mass (kg)						
							Dynamic <i>C_a</i>	Static <i>C_{0a}</i>	Dynamic <i>C₁</i>	Static <i>C_{0t}</i>	<i>D</i>	<i>A</i>	<i>B</i>	<i>L₅</i>	<i>L₆</i>	<i>L₇</i>	<i>L₈</i>	<i>L₉</i>	<i>Y</i>	<i>T</i>	<i>M₂</i>			<i>t₂</i>	<i>W₂</i>	<i>D₂</i>	<i>W</i>	<i>X</i>	
0.41	25	10	3.175	25.75	22.4	(18)	4300	5090	47.9	63.9	48	64	5	45	2.5	6.5	10	6.5	4.5	6.5	M4	7	25	35	56	4.5	0.52	0.42	
0.43							4300	5090	47.9	63.9																			0.43
0.53							4730	5820	65.1	90.5																			0.63
0.56							5110	6540	70.5	100																			0.65
0.53							5110	6540	70.5	100																			0.63
0.60							5130	6540	87.8	125																			1.04
0.64	5870	8000	100	155	1.13																								
0.69	5870	8000	100	155	1.24																								

Unit: mm



Model No.	Shaft dia. <i>d</i>	Lead <i>l</i>	Ball dia. <i>D_w</i>	Ball circle dia. <i>d_m</i>	Root dia. <i>d_r</i>	Screw shaft hollow <i>d_i</i>	Ball screw nut															
							Basic load rating(N)		Dimensions													
							Dynamic <i>C_r</i>	Static <i>C_{0r}</i>	<i>D</i>	<i>A</i>	<i>B</i>	<i>L₁</i>	<i>L₂</i>	<i>L₃</i>	<i>L₄</i>	<i>M₁</i>	<i>t₁</i>	<i>W₁</i>	<i>D₁</i>	<i>W</i>	<i>X</i>	
ΣCZ1610	16	10	3.175	16.75	13.4	(8)	4710	8110	48	64	5	46	3	4	10	3-M4	6	28	35	56	4.5	
ΣCZ1632		32					2990	4870				51										56
ΣCZ2010	20	10	3.175	20.75	17.4	(14)	8210	17500	54	70	6	56	4	4	10	3-M4	6	32	40	62	4.5	
ΣCZ2020		20					5290	10300				63										56
ΣCZ2040		40					3360	6170				56										56
ΣCZ2510	25	10	3.175	25.75	22.4	(18)	9110	21900	58	74	6	56	4	4	10	3-M4	6	38	45	66	4.5	
ΣCZ2520		20					5870	13200				63										56
ΣCZ2525		25					5870	13200				71										56



Unit: mm

Moment of inertia (kg·cm ²)	Mass (kg)	Ball spline nut																		Mass (kg)
		Basic load rating(N)		Basic torque(N·m)		Dimensions														
		Dynamic <i>C_r</i>	Static <i>C_{0r}</i>	Dynamic <i>C_t</i>	Static <i>C_{0t}</i>	<i>D₂</i>	<i>A₂</i>	<i>B₂</i>	<i>L₅</i>	<i>L₆</i>	<i>L₇</i>	<i>L₈</i>	<i>H</i>	<i>W₂</i>	<i>X₂</i>					
0.40	0.41	4300	5090	47.9	63.9	35	55	6	45	10.5	28.5	6.5	45	45	4.5	0.26				
0.43	0.43	4300	5090	47.9	63.9															
0.63	0.53	4730	5820	65.1	90.5	40	60	6	50	10.5	33.5	6.5	50	50	5.5	0.35				
0.65	0.56	5110	6540	70.5	100															
0.63	0.53	5110	6540	70.5	100	45	65	6	55	10.5	38.5	6.5	55	55	5.5	0.44				
1.04	0.60	5130	6540	87.8	125															
1.13	0.64	5870	8000	100	155															
1.24	0.69	5870	8000	100	155															