BALL SPLINE

BALL **SPLINE**

Ball Spline are shaft guides used for precise guidance of linear movements. They consist of a shaft with multiple pairs of longitudinal grooves and a ball spline nut. The nut contains ball cages filled with steel balls. They roll along the longitudinal grooves of the ground shaft and thus enable precise linear movements. Due to the angular arrangement of the force-transmitting elements, Ball Spline can absorb both radial forces and torque loads.

DOWNLOADS AND **APPLICATIONS**

Assembly instructions

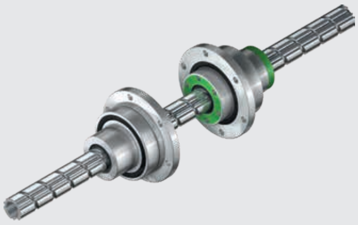
CAD configurator

Contents

1. Product overview

Linear Ball Spline Page 9

- Different nut types available
- Linearly freely movable
- Torque and radial load transmission
- With solid or hollow shaft
- Nominal diameter 13 – 32 mm



Ball Screw Spline Page 11

- Driven flange nuts
- Shaft with Ball Spline nut and Ball Screw nut
- With solid or hollow shaft
- Nominal diameter 16 – 32 mm

2. Features

The HIWIN Ball Spline is an anti-rotation shaft guide consisting mainly of a nut filled with steel balls and a shaft with several longitudinal grooves arranged in pairs. The steel balls roll in the raceways between the nut and shaft in a closed circuit and enable the nut to move along the shaft with low friction and high precision. The angular contact between the steel balls and the raceway in the nut and shaft enables radial forces and torques to be absorbed. Thanks to the integrated nut/bearing design, the Ball Spline can achieve high payloads with a compact design.

The Ball Spline has three sets of steel balls loaded in retainers, with face-to-face angular contact with the screw shaft. The optimized retainer design provides precise guided movement with high speed, acceleration and deceleration and secures the steel balls firmly, even when the nut is removed from the shaft.

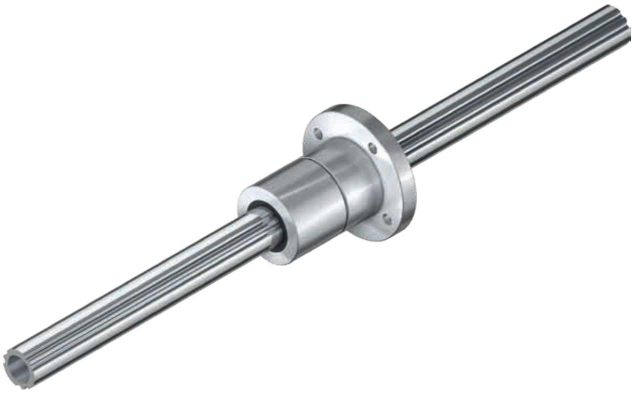
- **Transmission of torque**
  The steel balls traveling on the groove with angular contact offer relative movement between the nut and the screw to achieve torque transmission
- **Integral structure**
  The integration of the nut and support bearings allows the Ball Spline to achieve high precision and a compact design
- **Lubricant path**
  The optimized lubricant path allows grease to be directly guided to the ball track improving lubrication and increasing service life

3. Introduction of Ball Spline

3.1 Linear Ball Spline

Cylinder type (RS type)

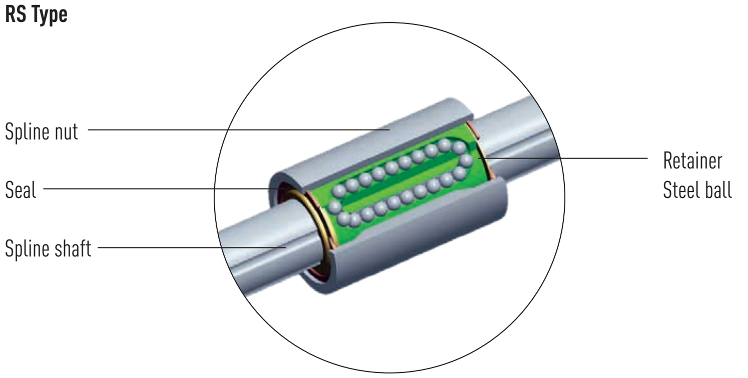
Flange type (FS type)



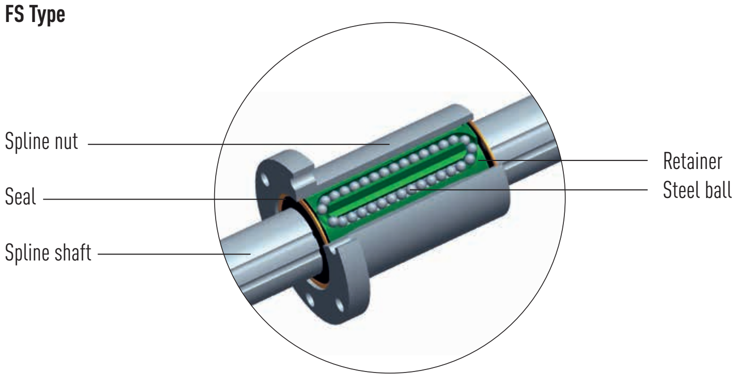
Rotary type (FSR type)

3.1.1 Technical structure

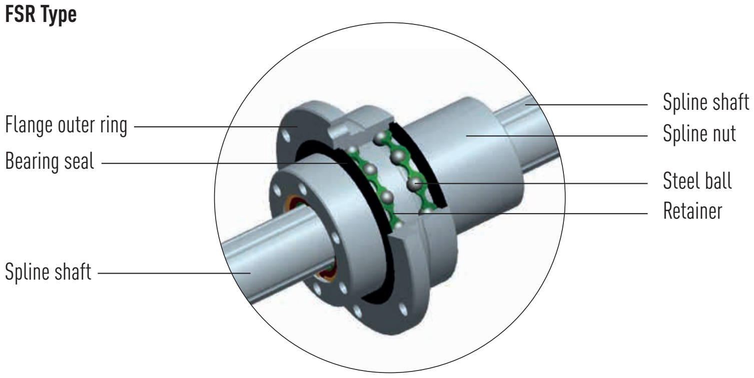
RS Type



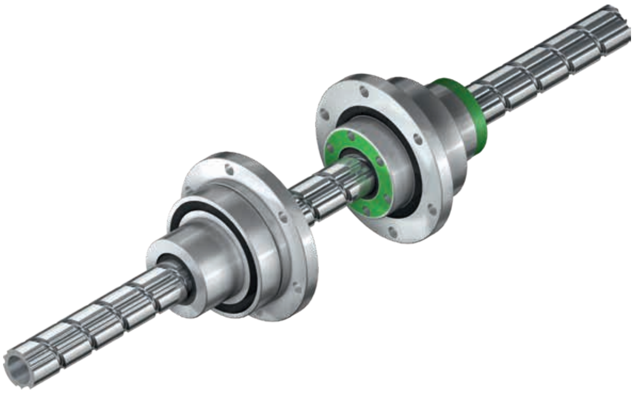
FS Type



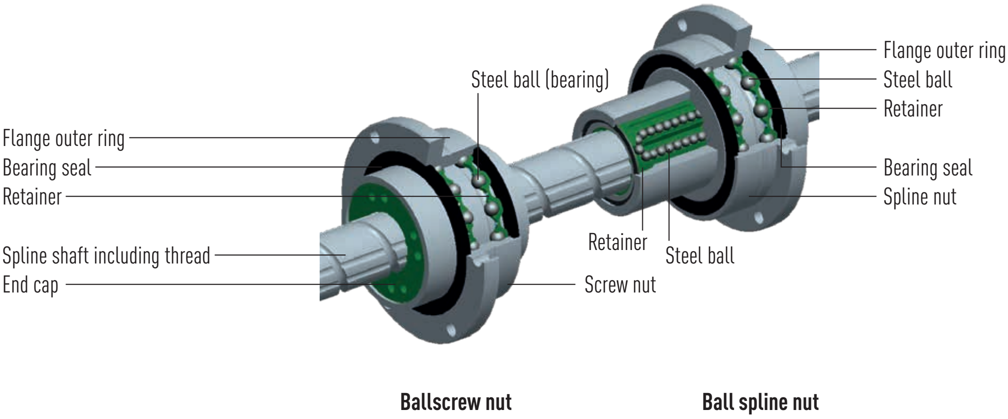
FSR Type



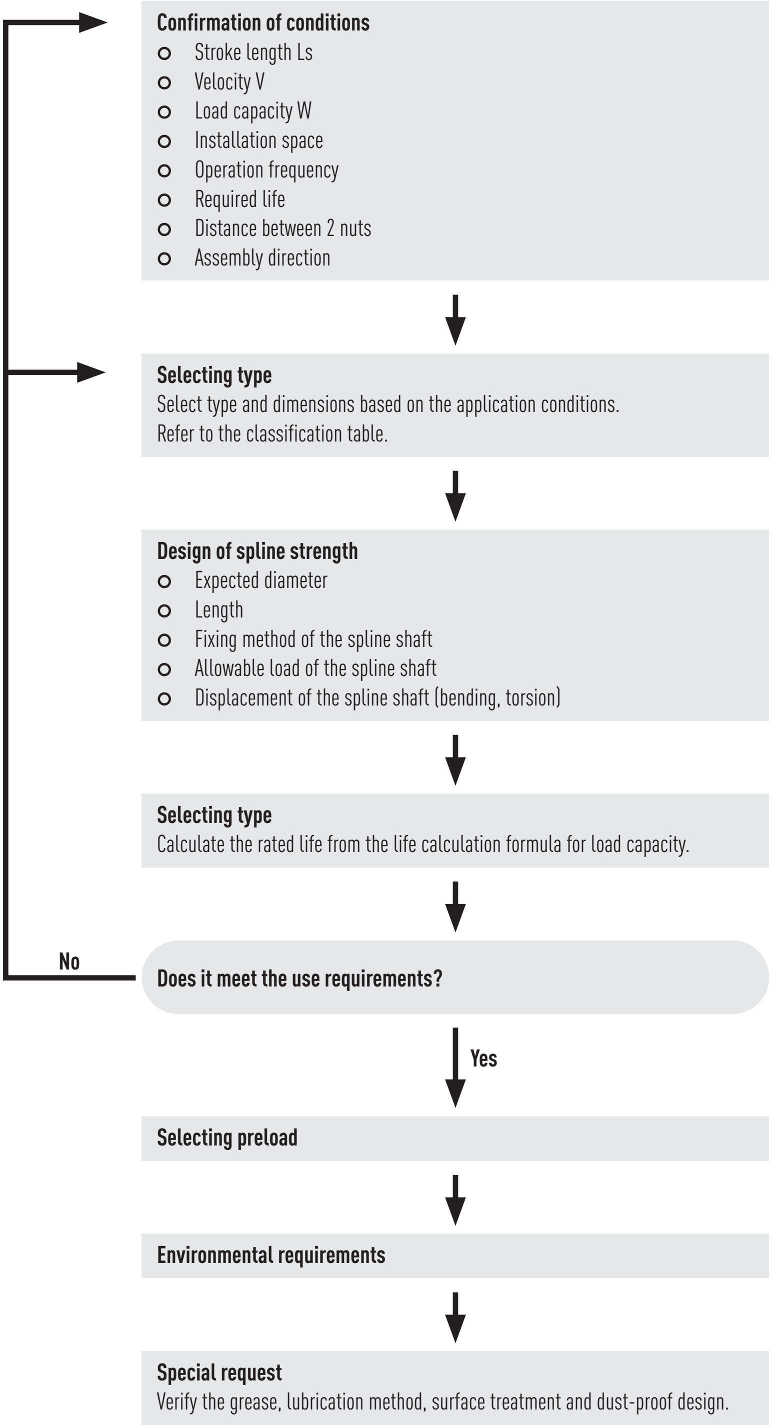
3.2 Ball Screw Splines (FBR type)



3.2.1 Technical structure



4. Selecting procedure of Ball Spline



Confirmation of conditions

- Stroke length Ls
- Velocity V
- Load capacity W
- Installation space
- Operation frequency
- Required life
- Distance between 2 nuts
- Assembly direction

Selecting type

Select type and dimensions based on the application conditions.
Refer to the classification table.

Design of spline strength

- Expected diameter
- Length
- Fixing method of the spline shaft
- Allowable load of the spline shaft
- Displacement of the spline shaft (bending, torsion)

Selecting type

Calculate the rated life from the life calculation formula for load capacity.

Does it meet the use requirements?

Selecting preload

Environmental requirements

Special request

Verify the grease, lubrication method, surface treatment and dust-proof design.

5. Calculation methods

5.1 Strength design of spline shaft

The Ball Spline can absorb radial loads and torsions. Sufficient strength of the Ball Spline must be ensured by calculating the load-bearing capacity and structural safety, especially in the case of high combined loads.

5.1.1 Spline shaft subjected to bending

When bending moments act on the spline shaft of the Ball Spline, the most suitable spline diameter can be calculated according to formula F 5.1:

F 5.1

$$M = \sigma \times Z \quad \dots \quad Z = \frac{M}{\sigma}$$

M Maximum torque acting on spline shaft [Nmm]
σ Allowable bending stress of spline shaft (98 N/mm^2)
Z Axial section modulus of the shaft
(5.77 × 10^2 mm^3 for specification SP20)

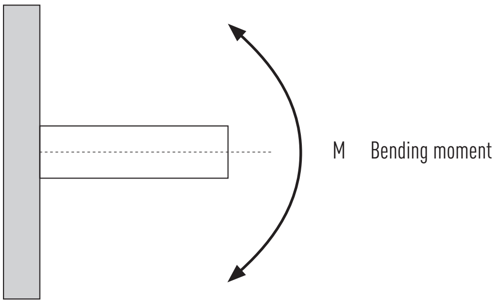


Fig. 5.1 **Schematic diagram of splines subjected to bending moments**

5.1.2 Spline shaft subjected to torsion

When torsions act on the Ball Spline shaft, the most suitable spline diameter can be calculated according to formula F 5.2:

F 5.2

$$T = \tau_a \times Z_p \quad \dots \quad Z_p = \frac{T}{\tau_a}$$

T Maximum torque [Nmm]
τ_a Allowable torsional stress on the spline shaft (49 N/mm^2)
Z_p Polar section modulus of the shaft
(specification 20 is 1.15 × 10^3 mm^3)

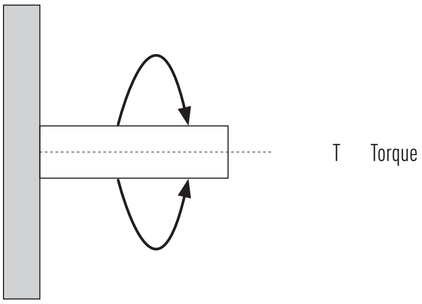


Fig. 5.2 **Schematic diagram of splines subjected to torques**

5.1.3 Spline shaft subjected to bending and torsion simultaneously

If the shaft is subjected to bending and torsional loads simultaneously, the required shaft diameter must be calculated separately for the equivalent bending moment (M_e) and for the equivalent torsional moment (T_e). The values must be compared and the larger of the two calculated shaft diameters must be used.

Equivalent bending moment

F 5.3

$$M_e = \frac{M + \sqrt{M^2 + T^2}}{2} = \frac{M}{2}\left\{1 + \sqrt{1 + \left(\frac{T}{M}\right)^2}\right\}$$

$$M_e = \sigma \times Z$$

Equivalent torque

F 5.4

$$T_e = \sqrt{M^2 + T^2} = M \times \sqrt{1 + \left(\frac{T}{M}\right)^2}$$

$$T_e = \tau_a \times Z_p$$

5.1.4 Rigidity of the spline shaft

Rigidity of the spline shaft is indicated by the torsional angle of the spline shaft of length 1 m, which is limited to about 0.25°.

F 5.5

$$\theta = 57{,}3 \times \frac{T \times L}{G \times I_p}$$

$$\text{Rigidity of the spline shaft} = \frac{\text{Torsional angle}}{\text{Unit length}} = \frac{\theta \times 1.000}{L} < \frac{1°}{4}$$

θ	Torsional angle [°]
L	Length of spline shaft [mm]
G	Shear modulus (7.9 × 104 N/mm^2)
I_p	Polar moment of inertia (specification 20 is 1.14 × 104 mm^4)

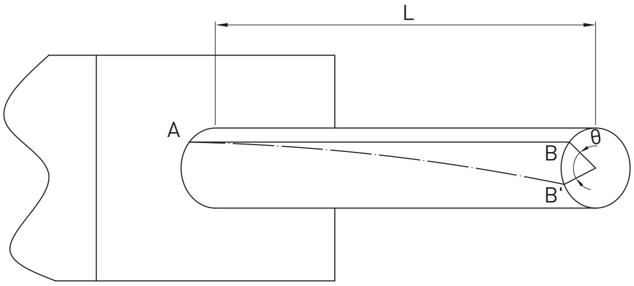
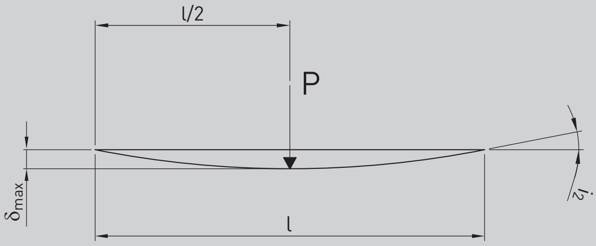
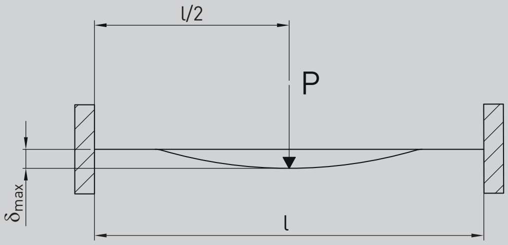
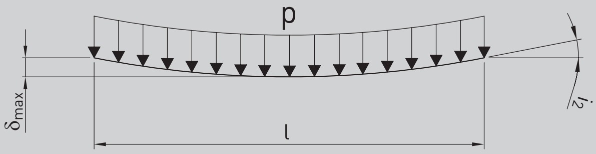
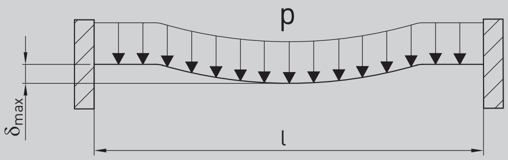
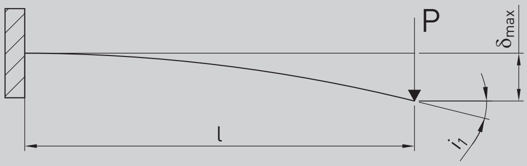
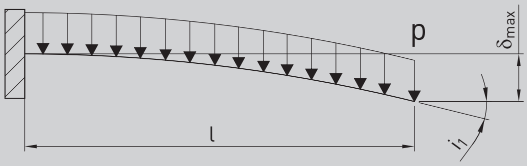
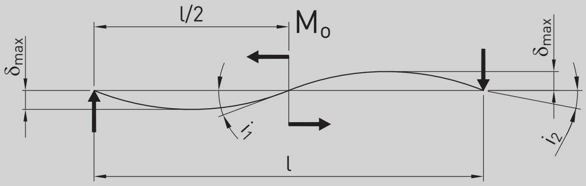
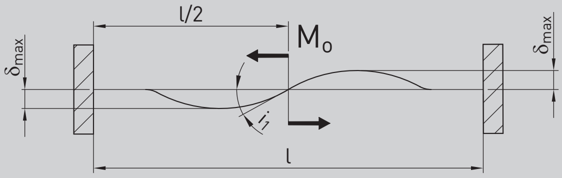


Fig. 5.3 **Schematic diagram of rigidity of the spline shaft**

5.1.5 Bending and bending angle of the spline shaft

The bending and bending angle of the ball spline shaft must be determined by calculation using the formulas corresponding to the actual load conditions.

Table 5.1 **Calculation of bending and bending angle**

Support method	Conditions of use	Calculation formula of bending	Calculation formula of bending angle
Both ends are free		$\delta_{max} = \frac{Pl^2}{48EI}$	$i_1 = 0$ $i_2 = \frac{Pl^2}{16EI}$
Both ends are fixed		$\delta_{max} = \frac{Pl^3}{192EI}$	$i_1 = 0$ $i_2 = 0$
Both ends are free		$\delta_{max} = \frac{5pl^4}{384EI}$	$i_2 = \frac{pl^3}{24EI}$
Both ends are fixed		$\delta_{max} = \frac{pl^4}{384EI}$	$i_2 = 0$
Either end is fixed		$\delta_{max} = \frac{Pl^3}{3EI}$	$i_1 = \frac{Pl^2}{2EI}$ $i_2 = 0$
Either end is fixed		$\delta_{max} = \frac{pl^4}{8EI}$	$i_1 = \frac{pl^3}{6EI}$ $i_2 = 0$
Neither end is fixed		$\delta_{max} = \frac{\sqrt{3}M_o l^2}{216EI}$	$i_1 = \frac{M_o l}{12EI}$ $i_2 = \frac{M_o l}{24EI}$
Both ends are fixed		$\delta_{max} = \frac{M_o l^2}{216EI}$	$i_1 = \frac{M_o l}{16EI}$ $i_2 = 0$

δ_{max}	Maximum bending [mm]	I	Geometric moment [mm^4]	P	Concentrated load [N]
M_o	Torque [Nmm]	i_1	Bending angle at support point	p	Uniform load [N/mm]
l	Span moment [mm]	i_2	Bending angle at loading point	E	Modulus of longitudinal elasticity 2.06 × 10^5 [N/mm^2]

5.1.6 Section characteristics of spline shafts

Table 5.2 **Characteristics of the spline shaft cross-section**

Nominal diameter		I: Geometric moment of inertia [mm^4]	Z: Cross-section coefficient [mm^3]	I_p: Polar moment of inertia [mm^4]	Z_p: Coefficient of the polar cross-section [mm^3]
13	Solid shaft	1.32×10^3	2.09×10^2	2.70×10^3	4.19×10^2
	Hollow shaft	1.29×10^3	2.00×10^2	2.63×10^3	4.09×10^2
16	Solid shaft	3.09×10^3	3.90×10^2	6.18×10^3	7.80×10^2
	Hollow shaft	2.37×10^3	2.99×10^2	4.74×10^3	5.99×10^2
20	Solid shaft	7.61×10^3	7.67×10^2	1.52×10^4	1.53×10^3
	Hollow shaft	5.72×10^3	5.77×10^2	1.14×10^4	1.15×10^3
25	Solid shaft	1.86×10^4	1.50×10^3	3.71×10^4	2.99×10^3
	Hollow shaft	1.34×10^4	1.08×10^3	2.68×10^4	2.16×10^3
32	Solid shaft	5.01×10^4	3.15×10^3	9.90×10^4	6.27×10^3
	Hollow shaft	3.64×10^4	2.29×10^3	7.15×10^4	4.53×10^3

5.1.7 Critical velocity of the spline shaft

When the ball spline shaft is driven by a motor and the rotation speed of the spline shaft increases closely to the resonance frequency, the mechanical stress on the ball spline increases significantly and can lead to bad running performance, vibration and even mechanical failure

Critical velocity

F 5.6

$$N_c = \frac{60\lambda^2}{2\pi \times l_b^{\,2}} \times \sqrt{\frac{E \times 10^3 \times I}{\gamma \times A}} \times 0.8$$

N_c Critical velocity [min^{-1}]
l_b Distance between installation surfaces [mm]
E Modulus of longitudinal elasticity [2.06×10^5 N/mm^2]
I Minimal geometrical moment of inertia [mm^4]
γ Density (specific center of gravity) [7.85×10^5 kg/mm^3]
A Spline shaft cross-sectional area [mm^2]
λ Factor according to the installation method
1 Fixed – not fixed: $\lambda = 1.875$ (see Fig. 5.4)
2 Supported – not supported: $\lambda = 3.142$ (see Fig. 5.5)
3 Fixed – supported: $\lambda = 3.927$ (see Fig. 5.6)
4 Fixed – fixed: $\lambda = 4.73$ (see Fig. 5.7)

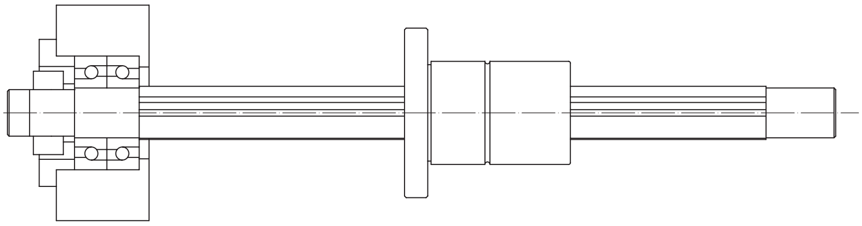


Fig. 5.4 **Schematic diagram of spline shaft: fixed – free**

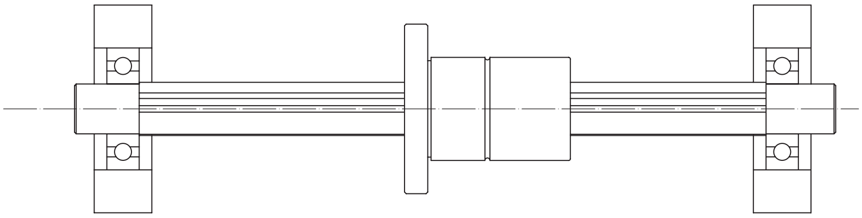


Fig. 5.5 **Schematic diagram of spline shaft: supported – supported**

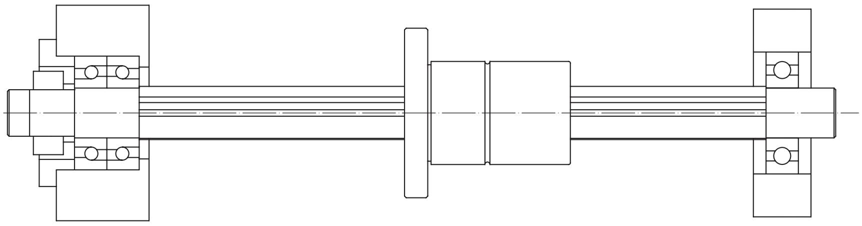


Fig. 5.6 **Schematic diagram of spline shaft: fixed – supported**

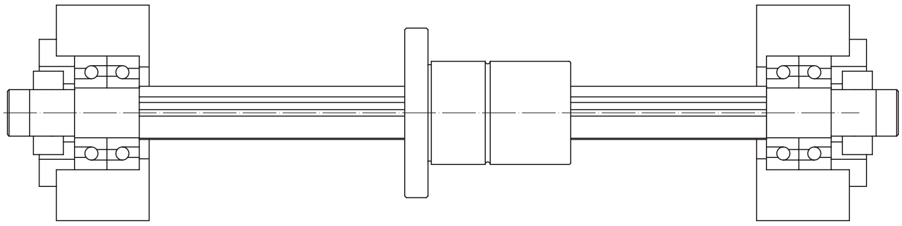


Fig. 5.7 **Schematic diagram of spline shaft: fixed – fixed**

5.2 Predicting life

5.2.1 Rated life

The life of a Ball Spline can vary considerably even if it is manufactured from the same batch and used under the same motion conditions. Therefore, as a basis for calculating the life of a linear motion system, use the rated life as defined below.
The rated life is the total running distance that can be achieved by having a batch of identical linear motion systems moving separately under the same conditions, 90 % of which do not show metal fatigue.

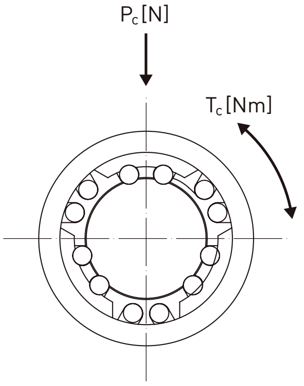


Fig. 5.8 Schematic diagram of the Ball Spline subjected to stress

The running of the Ball Spline can be divided into three types of torsions, radial loads and moments. The respective rated life can be obtained according to F 5.7, F 5.8, F 5.9 and F 5.10. (The basic rated load in each direction of load is recorded in the dimensional table of each model number.)

When subjected to torque load

F 5.7

$$L = \left(\frac{f_T \times f_C}{f_W} \times \frac{C_T}{T_C} \right)^3 \times 50$$

When subjected to radial load

F 5.8

$$L = \left(\frac{f_T \times f_C}{f_W} \times \frac{C}{P_C} \right)^3 \times 50$$

L	Rated life [km]
C_T	Basic dynamic rated torque [Nm]
T_C	Calculated value of applied torque [Nm]
C	Basic dynamic rated load [N]
P_C	Calculated value of radial load [N]
f_T	Temperature coefficient (see Fig. 5.9 on Page 18)
f_C	Contact coefficient (see Table 5.3 on Page 18)
f_W	Load coefficient (see Table 5.4 on Page 19)

When subjected to both torsional and radial loads simultaneously, the equivalent radial load can be calculated according to formula F 5.9 and then the life can be calculated.

F 5.9

$$P_E = P_C + \frac{4 \times T_C \times 10^3}{i \times dp \times \cos\alpha}$$

P_E	Equivalent radial load [N]
$\cos\alpha$	Constant angle (FBR type: α = 70°)
i	3 rows of steel balls under load for specification 20
dp	Ball center diameter [mm]

Calculating life time

After calculating the rated life (L) using the above formulas, the life time can be calculated according to formula F 5.9 when the number of strokes and times are fixed.

F 5.10

$$L_h = \frac{L \times 10^3}{2 \times l_s \times n_1 \times 60}$$

L_h	Life time [h]
l_s	Stroke length [m]
n_1	Cycles per minute [min^{-1}]

5.2.2 Temperature coefficient f_T

When using a Ball Spline in operating temperatures exceeding 100 °C, multiply the temperature coefficient of Fig. 5.9 when calculating the life, taking into account the adverse effects caused by high temperatures. Also, note that it is necessary to use Ball Spline products suitable for high temperatures.

Note: In case of operating above 80 °C, the material of the gasket and retainer must be changed to a material for the high-temperature specification accordingly.

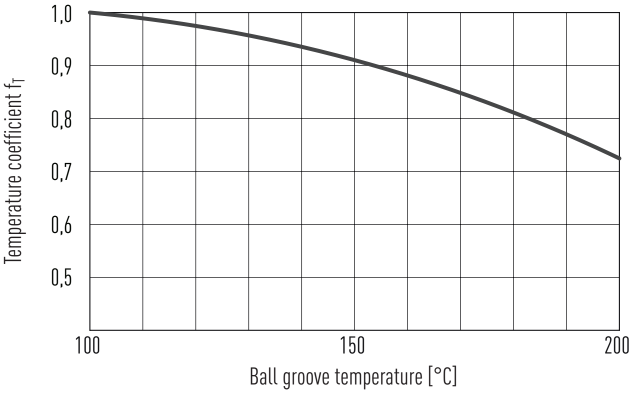


Fig. 5.9 **Temperature coefficient f_T**

5.2.3 Contact coefficient f_c

When multiple nuts are mounted closely and working in linear motion, it is difficult to get a uniform distribution of loads due to the moment load and mounting accuracy. Therefore when using multiple nuts closely, multiply the basic rated load (C) and (C_0) by corresponding contact coefficients in Table 5.3.

Table 5.3 **Contact coefficient f_c**

Number of spline nuts mounted closely	Contact coefficient f_c
2	0.81
3	0.72
4	0.66
5	0.61
Usual use	1.00

Note: If the load is expected to be non-uniform in large installations, please refer to the contact coefficients in Table 5.3.

5.2.4 Load coefficient f_w

Most machines will have vibration and shock during operation. Vibration is generated during high-speed movement. Shock is caused by frequent starting and stopping. It is very difficult to calculate all correctly. Therefore, when the actual load on the linear motion system is not available, or when the effects of velocity and vibration are significant, please divide the basic rated load (C) and (C_0) by the load coefficients obtained from experience in Table 5.4.

Table 5.4 **Load coefficient f_w**

Vibration/shock	Velocity v [m/s]		Load coefficient f_w
Low	At mini speed per hour	$v \leq 0.25$	1.0–1.2
Small	At low speed per hour	$0.25 < v \leq 1.0$	1.2–1.5
Medium	At medium speed per hour	$1 < v \leq 2$	1.5–2.0
High	At high speed per hour	$v > 2$	2.0–3.5

5.2.5 Shape of the spline shaft cross-section

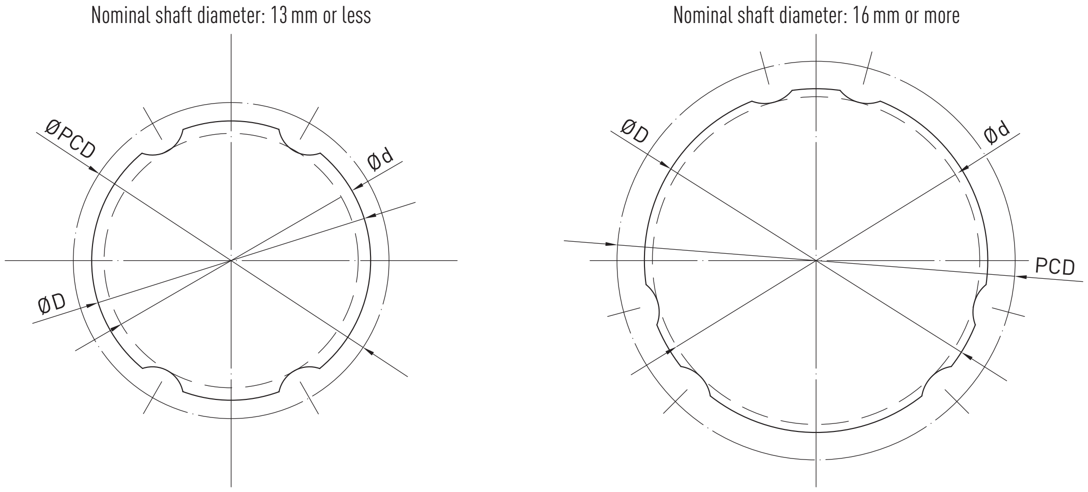


Fig. 5.10 **Diagram of the Ball Spline cross-section**

5.2.6 Shape of the hollow spline shaft cross-section

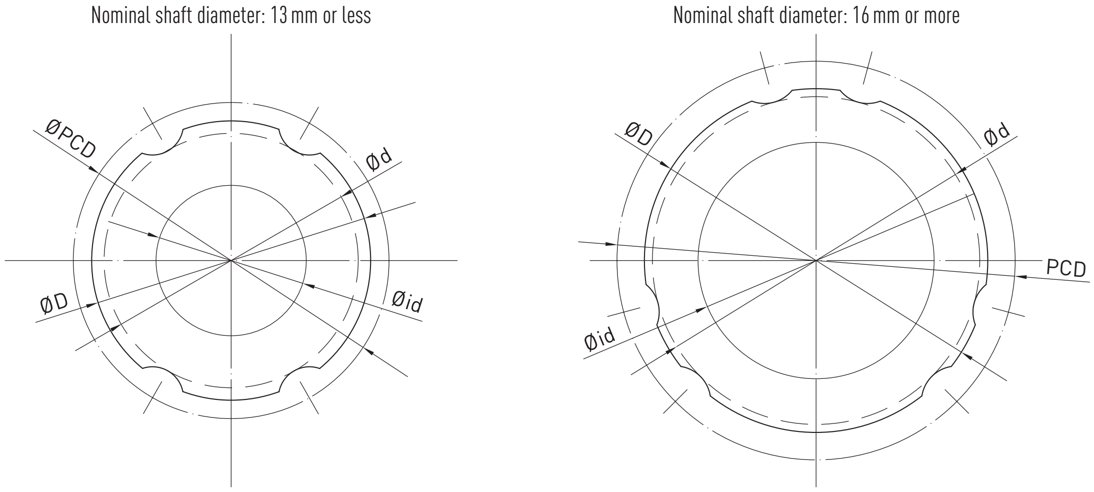


Fig. 5.11 **Diagram of the hollow Ball Spline cross-section**

Table 5.5 **Parameters of the spline shaft cross-section**

Nominal shaft diameter	**13**	**16**	**20**	**25**	**32**
Groove valley diameter Ød [1]	12.02	15.02	18.92	23.62	30.42
Ball center PCD	14.8	17.8	22.1	27.6	33.2
Outer diameter ØD	13	16	20	25	32
Allowable outer diameter tolerance	$^{0}_{-0.018}$		$^{0}_{-0.021}$		$^{0}_{-0.025}$
Hollow hole Øid	7	11	14	18	23

Unit: mm

[1] The groove valley diameter Ød must be the value where no groove is left after processing.

5.2.7 Calculating average load

If the load applied to the ball spline varies due to operating conditions that change over time, then these variable loads must be taken into account when calculating the life expectancy. A practical example of variable loads would be an industrial robot arm equipped with a ball spline that transports a work piece from the initial position to the target position, then deposits the work piece and returns to the starting position without payload. The average load (P_m) corresponds to a constant equivalent load under which the ball spline achieves the same nominal life as it would achieve under the actual variable loading conditions of the ball spline.

F 5.11

$$P_m = \times \sqrt[3]{\frac{1}{L} \times \sum_{n=1}^{n} \left(P_n^3 \times L_n\right)}$$

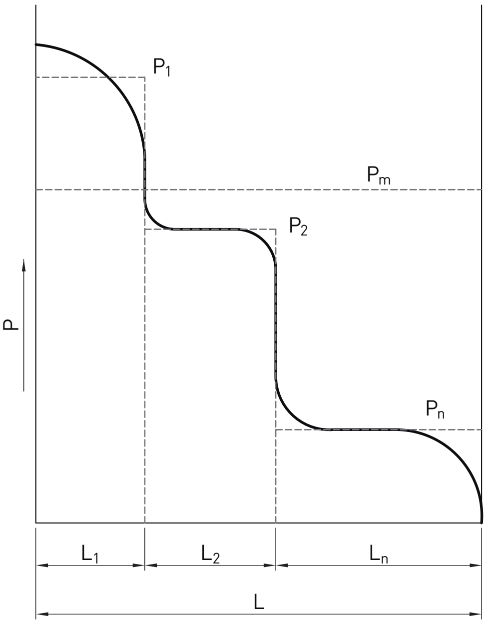
P_m	Average load [N]
P_n	Variable load [N]
L	Total running distance [mm]
L_n	Distance travelling during P_n [mm]

5.2.8 The case of step load

F 5.12

$$P_m = \times \sqrt[3]{\frac{1}{L} \times \left(P_1^3 \times L_1 + P_2^3 \times L_2 \ \ldots + P_n^3 \times L_n\right)}$$

P_m	Average load [N]
P_n	Variable load [N]
L	Total running distance [mm]
L_n	Distance travelling during P_n [mm]



P	Load [N]
L	Total running distance [mm]

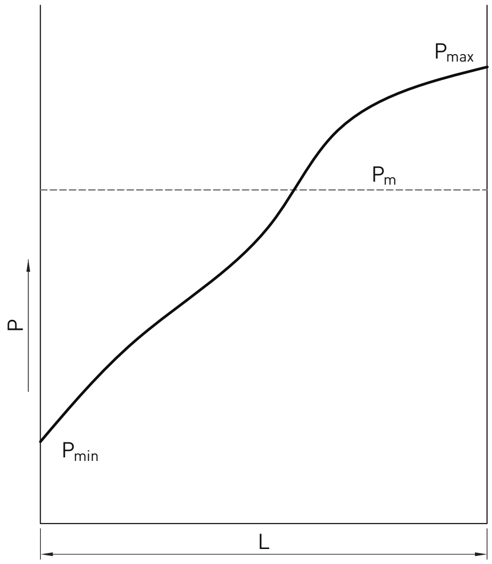
Fig. 5.12 **Diagram of average load in the case of step load**

5.2.9 The case of monotonic load fluctuation

F 5.13

$$P_m \fallingdotseq \frac{1}{3}\left(P_{min} + 2 \times P_{max}\right)$$

P_{min}	Minimum load [N]
P_{max}	Maximum load [N]



P	Load [N]
L	Total running distance [mm]

Fig. 5.13 **Diagram of average load in the case of monotonic load fluctuation**

5.2.10 Sinusoidal load fluctuation

F 5.14

$$P_m \approx 0{,}65 \times P_{max}$$

See Fig. 5.14

F 5.15

$$P_m \approx 0{,}75 \times P_{max}$$

See Fig. 5.15

P_m	Average load [N]
P_{max}	Maximum load [N]
P	Load [N]
L	Total running distance [mm]

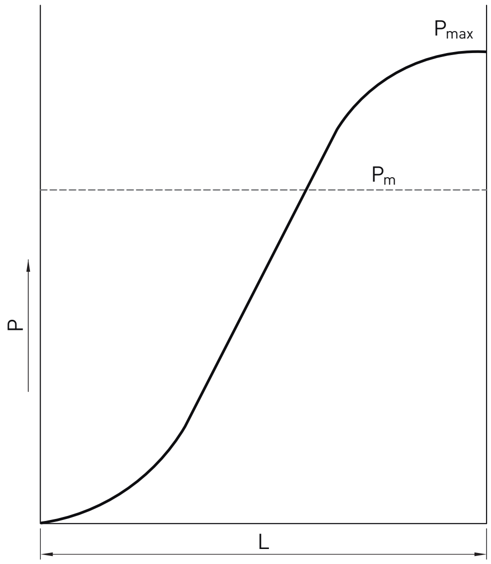


Fig. 5.14 **Diagram of average load for sinusoidal load fluctuation (see formula F 5.14)**

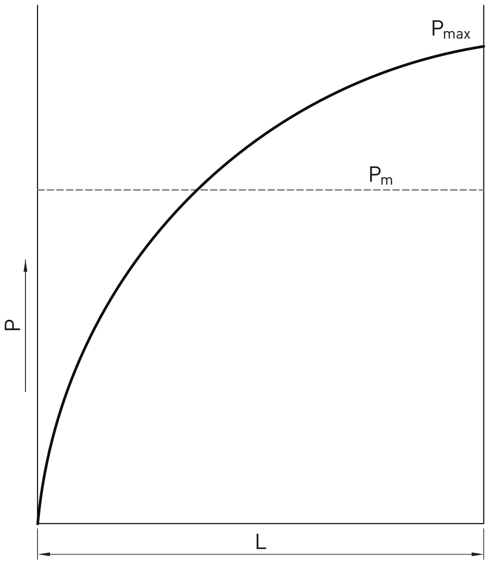


Fig. 5.15 **Diagram of average load for sinusoidal load fluctuation (see formula F 5.15)**

6. Selecting preload

The preload of the Ball Spline significantly influences accuracy and rigidity, so it is necessary to select the appropriate clearance (or preload) for the application. Clearance values are specified for each model number and can therefore be selected appropriately according to the conditions of use.

6.1 Preload and rigidity

Preload is a load applied to the ball beforehand to eliminate clearance in the rotation direction and improve rigidity. When preload is applied, the Ball Spline increases rigidity according to the strength of the preload. Fig. 6.1 shows the displacement in the direction of rotation when applying a rotational torsion.
As shown in Fig. 6.1, the effect of preload is maintained up to 2.8 times the preload load. Compared with the time without preload, the displacement becomes one-half of the same torsion and the rigidity is more than 2 times.

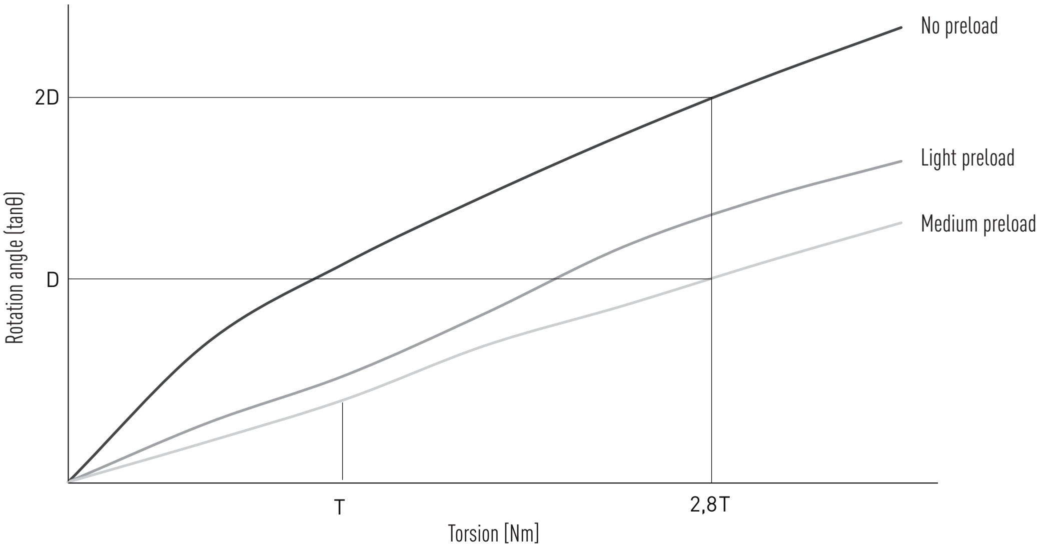


Fig. 6.1 **Rotation angle over torsion**

6.2 Conditions and benchmarks for use in the selection of preload

Table 6.1 indicates the benchmarks for selection of clearance in the direction of rotation according to the conditions of use of the Ball Spline.

Clearance in the direction of rotation of the Ball Spline significantly influences the accuracy or rigidity of the Ball Spline. Therefore, it is important to select the appropriate clearance according to the application. Generally, products with preload are used. There is a high vibration shock in the case of a repeated rotating motion or a reciprocating linear motion, so applying preload will significantly improve the rigidity and accuracy.

Table 6.1 **Selected benchmark for clearance of the Ball Spline in the direction of rotation**

Clearance in the direction of rotation	Conditions of use	Typical applications
No preload	– Where it is intended to drive smoothly with a small force – Where the torsion always acts in a certain direction	– Various metering instruments – Automatic drawing machine – Shape measuring instruments – Dynamometer – Winding machine – Automatic welding machine – Boring and grinding machine main shaft – Automatic packing machine
Light preload	– Where the cantilever load or moment is applied – Where high accuracy of repetition is required – Alternating load is applied	– Rocker arm of industrial robots – Various automatic loading and unloading machines – Automatic coating guide shaft – Electric discharge machine main shaft – Stamping die guide shaft – Drilling machine main shaft
Medium preload	– Where high rigidity is required and vibration shock is prone to occur. – Receives a moment load with a single spline nut	– The steering shaft of construction vehicles – Paste welding machine shaft – Automatic plate tool table indexing shaft

Table 6.2 **Clearance and preload range for each specification in the direction of rotation**

Shaft diameter	No preload	Light preload	Medium preload
13	–	0–0.02C	0.05C–0.07C
16, 20	–	0–0.02C	0.05C–0.07C
25, 32	–	0–0.02C	0.05C–0.07C

C: Basic rated dynamic load

7. RS, FS and FSR types

7.1 HIWIN order code for Ball Spline RS, FS and FSR types

SP	20	2	FS	400	500	C	S

Ball Spline

Spline shaft outer diameter

Number of spline nuts on one shaft:
None: 1 pc

Nut type:
RS: Cylinder type
FS: Flange type
FSR: Rotary type

Spline shaft marking:
S: Solid shaft
None: Hollow shaft

Accuracy:
C: Normal grade
H: High grade
P: Precision grade

Total length of spline shaft [mm]

Length of straight groove [mm]

7.2 Selecting accuracy

7.2.1 The grade of accuracy

The grade of accuracy of the Ball Spline is expressed in terms of oscillation of the outer diameter of the spline nut against the supporting part of the spline shaft. It is divided into normal (C), high (H) and precision (P) which are shown in Fig. 7.1.

7.2.2 Accuracy indication

RS Type

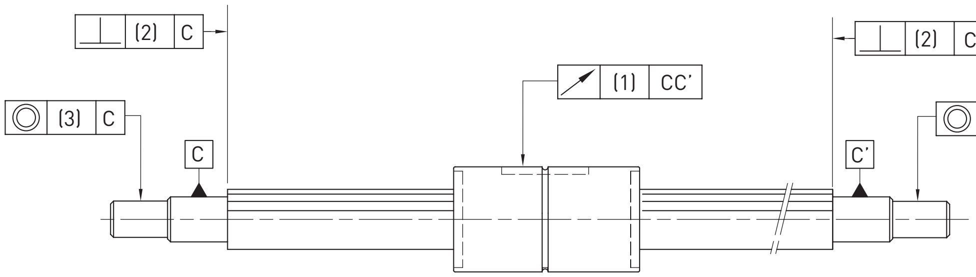


Fig. 7.1 **Measurement items of the accuracy of RS type Ball Spline**

Table 7.1 **Runout accuracy of RS type Ball Spline**

Total length of spline shaft		Nominal shaft diameter														
		13			**16**			**20**			**25**			**32**		
Above	**Below**	**C**	**H**	**P**	**C**	**H**	**P**	**C**	**H**	**P**	**C**	**H**	**P**	**C**	**H**	**P**
—	**200**	56	34	18	56	34	18	56	34	18	53	32	18	53	32	18
200	**315**	71	45	25	71	45	25	71	45	25	58	39	21	58	39	21
315	**400**	83	53	31	83	53	31	83	53	31	70	44	25	70	44	25
400	**500**	95	62	38	95	62	38	95	62	38	78	50	29	78	50	29
500	**630**	112	—	—	112	—	—	112	—	—	88	57	34	88	57	34
800	**—**	—	—	—	—	—	—	—	—	—	103	68	42	103	68	42
1,000	**—**	—	—	—	—	—	—	—	—	—	124	83	—	124	83	—

Unit: µm

Table 7.2 **Geometric accuracy of RS type Ball Spline**

Nominal shaft diameter	Shoulder verticality (2)			Shoulder concentricity (3)		
	Accuracy					
	C	**H**	**P**	**C**	**H**	**P**
13	27	11	8	46	19	12
16	27	11	8	46	19	12
20	27	11	8	46	19	12
25	33	13	9	53	22	13
32	33	13	9	53	22	13

Unit: µm

FS Type

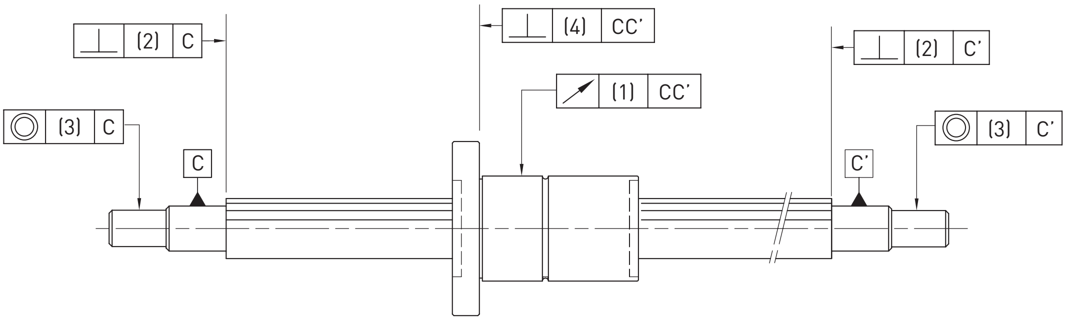


Fig. 7.2 **Measurement items of the accuracy of FS type Ball Spline**

Table 7.3 **Runout accuracy of FS type Ball Spline**

Total length of spline shaft		Nominal shaft diameter														
		13			**16**			**20**			**25**			**32**		
Above	**Below**	**C**	**H**	**P**	**C**	**H**	**P**	**C**	**H**	**P**	**C**	**H**	**P**	**C**	**H**	**P**
—	**200**	56	34	18	56	34	18	56	34	18	53	32	18	53	32	18
200	**315**	71	45	25	71	45	25	71	45	25	58	39	21	58	39	21
315	**400**	83	53	31	83	53	31	83	53	31	70	44	25	70	44	25
400	**500**	95	62	38	95	62	38	95	62	38	78	50	29	78	50	29
500	**630**	112	—	—	112	—	—	112	—	—	88	57	34	88	57	34
630	**800**	—	—	—	—	—	—	—	—	—	103	68	42	103	68	42
800	**1,000**	—	—	—	—	—	—	—	—	—	124	83	—	124	83	—

Unit: μm

Table 7.4 **Geometric accuracy of FS type Ball Spline**

Nominal shaft diameter	Shoulder verticality (2)			Shoulder concentricity (3)			Verticality (4)		
	Accuracy								
	C	**H**	**P**	**C**	**H**	**P**	**C**	**H**	**P**
13	27	11	8	46	19	12	39	16	11
16	27	11	8	46	19	12	39	16	11
20	27	11	8	46	19	12	39	16	11
25	33	13	9	53	22	13	39	16	11
32	33	13	9	53	22	13	39	16	11

Unit: μm

FSR Type

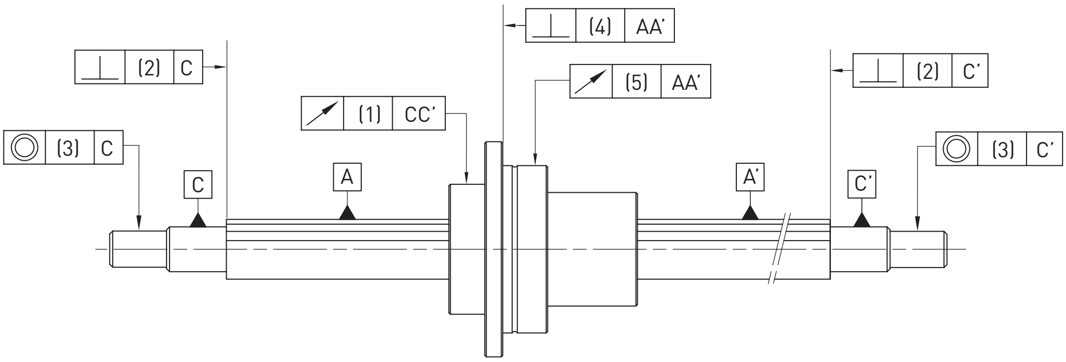


Fig. 7.3 **Measurement items of the accuracy of FSR type Ball Spline**

Table 7.5 **Runout accuracy of FSR type Ball Spline**

Total length of spline shaft		Nominal shaft diameter														
		13			16			20			25			32		
Above	**Below**	C	H	P	C	H	P	C	H	P	C	H	P	C	H	P
—	**200**	56	34	18	56	34	18	56	34	18	53	32	18	53	32	18
200	**315**	71	45	25	71	45	25	71	45	25	58	39	21	58	39	21
315	**400**	83	53	31	83	53	31	83	53	31	70	44	25	70	44	25
400	**500**	95	62	38	95	62	38	95	62	38	78	50	29	78	50	29
500	**630**	112	—	—	112	—	—	112	—	—	88	57	34	88	57	34
630	**800**	—	—	—	—	—	—	—	—	—	103	68	42	103	68	42
800	**1,000**	—	—	—	—	—	—	—	—	—	124	83	—	124	83	—

Unit: μm

Table 7.6 **Geometric accuracy of FSR type Ball Spline**

Nominal shaft diameter	Shoulder verticality (2)			Shoulder concentricity (3)			Outer ring verticality (4)			Outer ring yaw (5)		
	Accuracy											
	C	H	P	C	H	P	C	H	P	C	H	P
16	27	11	8	46	19	12	29	18	13	32	21	16
20	27	11	8	46	19	12	29	18	13	32	21	16
25	33	13	9	53	22	13	32	21	16	32	21	16
32	33	13	9	53	22	13	32	21	16	32	21	16

Unit: μm

7.3 Product dimensions and specifications

RS type

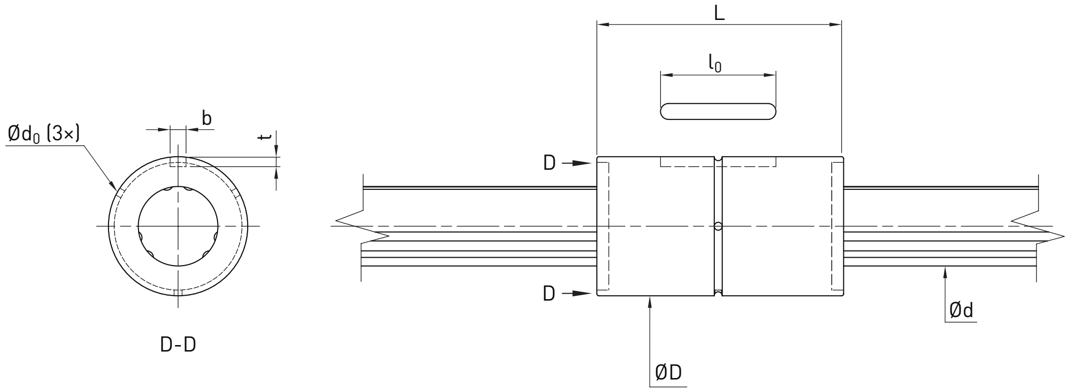


Table 7.7 **Product dimensions and specifications of RS type Ball Spline**

Nominal shaft diameter	Basic rated load		Basic rated torsion		Allowable static torque	Outer diameter	Length	Keyway width	Keyway depth	Keyway length	Lubrication hole
	C [kN]	**C_0 [kN]**	**C_{τ} [Nm]**	**$C_{0\tau}$ [Nm]**	**MA [Nm]**	**D**	**L**	**b H8**	**$t^{+0.1}_{0}$**	**l_0**	**d_0**
13	4.07	5.99	5.98	10.88	19.6	24	36	3.0	1.5	15.0	1.5
16	7.20	13.50	32.10	34.40	67.6	31	50	3.5	2.0	17.5	2.0
20	10.40	20.00	57.80	63.20	118.0	35	63	4.0	2.5	29.0	2.0
25	15.40	27.50	106.50	108.80	210.0	42	71	4.0	2.5	36.0	3.0
32	20.50	34.40	181.50	173.10	290.0	49	80	4.0	2.5	42.0	3.0

All dimensions stated without a unit are in mm

FS type

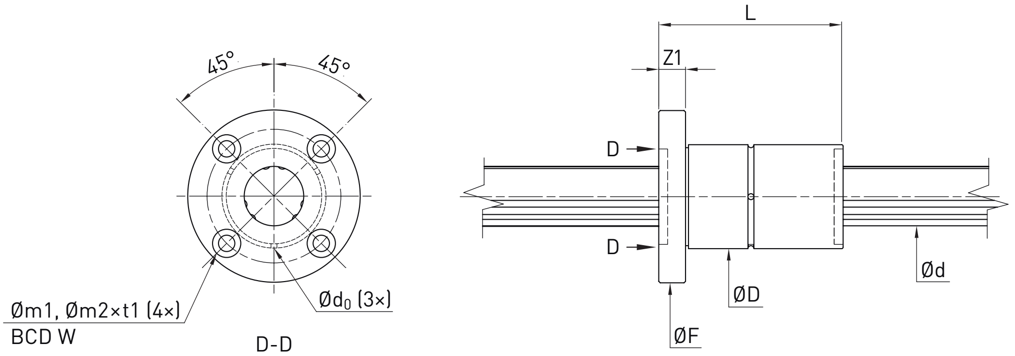


Table 7.8 **Product dimensions and specifications of FS type Ball Spline**

Nominal shaft diameter	Basic rated load		Basic rated torsion		Allowable static torque	Outer diameter	Flange outer diameter	Length	Z1	Lubrication hole	W	m1	m2 × t1
	C [kN]	**C_0 [kN]**	**C_{τ} [Nm]**	**$C_{0\tau}$ [Nm]**	**MA [Nm]**	**D**	**F**	**L**		**d_0**			
13	4.07	5.99	5.98	10.88	19.6	24	44	36	7	1.5	33	4.5	8 × 4.4
16	7.20	13.50	32.10	34.40	67.6	31	51	50	7	2.0	40	4.5	8 × 4.4
20	10.40	20.00	57.80	63.20	118.0	35	58	63	9	2.0	45	5.5	9.5 × 5.4
25	15.40	27.50	106.50	108.80	210.0	42	65	71	9	3.0	52	5.5	9.5 × 5.4
32	20.50	34.40	181.50	173.10	290.0	49	77	80	10	3.0	62	6.6	11 × 6.5

All dimensions stated without a unit are in mm

FSR type

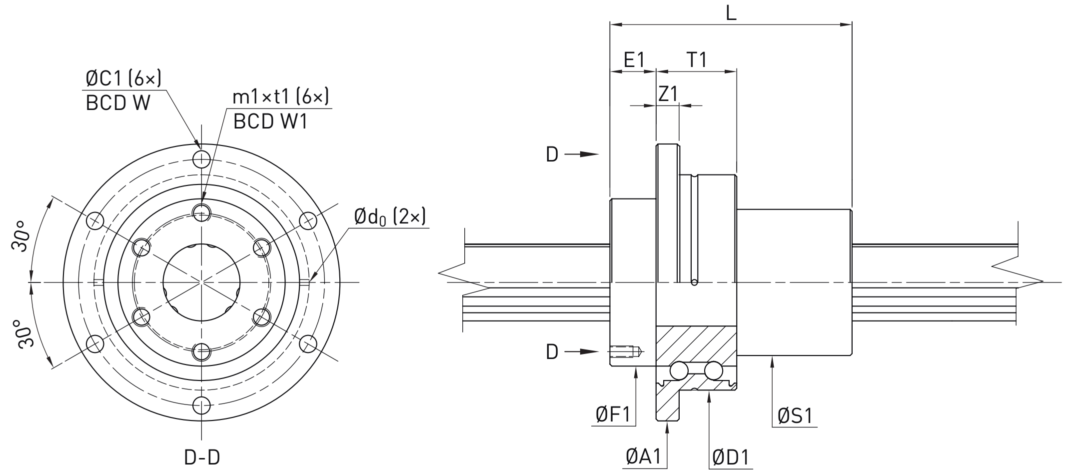


Table 7.9 **Product dimensions and specifications of FSR type Ball Spline**

Nominal shaft diameter	Basic rated load		Basic rated torsion		Allowable static torque	Outer diameter	Flange outer diameter	Total length	F1	S1	T1	E1	Z1	W	W1	m1 × t1	C1	Lubri-cation hole	Outer ring basic rated load	
	C [kN]	**C_0 [kN]**	**C_τ [Nm]**	**$C_{0\tau}$ [Nm]**	**MA [Nm]**	**D**	**A1**	**L**										**d_0**	**C_a [kN]**	**C_{0a} [kN]**
16	7.2	13.5	32.1	34.4	67.6	48	64	50	36.0	31	21	10	6	56	30	M4 × 6	4.5	1.5	9.3	11.5
20	10.4	20.0	57.8	63.2	118.0	56	72	63	43.5	35	21	12	6	64	36	M5 × 8	4.5	1.5	9.8	13.3
25	15.4	27.5	106.5	108.8	210.0	66	86	71	52.0	42	25	13	7	75	44	M5 × 8	5.5	2.5	13.1	22.0
32	20.5	34.4	181.5	173.1	290.0	78	103	80	63.0	52	25	17	8	89	54	M6 × 10	6.6	2.5	13.7	25.2

All dimensions stated without a unit are in mm

8. FBR and FBL types

8.1 HIWIN order code for Ball Spline FBR and FBL types

SP 20 **FBR** 400 **500** S

- **Ball Spline**: SP
- **Spline shaft outer diameter**: 20
- **Nut type**: FBR
  - FBR: Right rotation
  - FBL: Left rotation
- **Length of straight groove [mm]**: 400
- **Total length of spline shaft [mm]**: 500
- **Spline shaft marking**: S
  - S: Solid shaft
  - None: Hollow shaft

8.2 Selecting accuracy

8.2.1 Accuracy specification

The compound Ball Spline consists of a ball screw nut and a Ball Spline nut, and is made according to the following specifications and inspected in accordance with Fig. 8.1 and Table 8.1.

Ball screw
Axial clearance: 0
Lead accuracy: C4 grade

Ball Spline
Clearance in the direction of rotation: 0 (light preload)
Precision grade: H grade

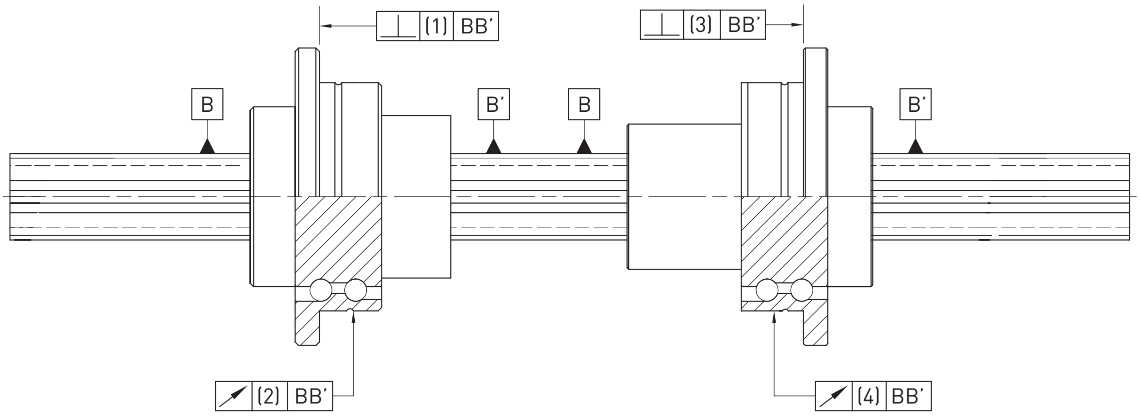


Fig. 8.1 **Measurement items of the accuracy of Ball Screw Splines**

Table 8.1 **Geometric accuracy of Ball Screw Splines**

Nominal shaft diameter	Ballscrew nut		Ball spline nut	
	Verticality (1)	**Runout (2)**	**Verticality (3)**	**Runout (4)**
16	16	20	18	21
20	16	20	18	21
25	18	24	21	21
32	18	24	21	21

Unit: μm

8.3 Product dimensions and specifications for compound Ball Spline

FBR type

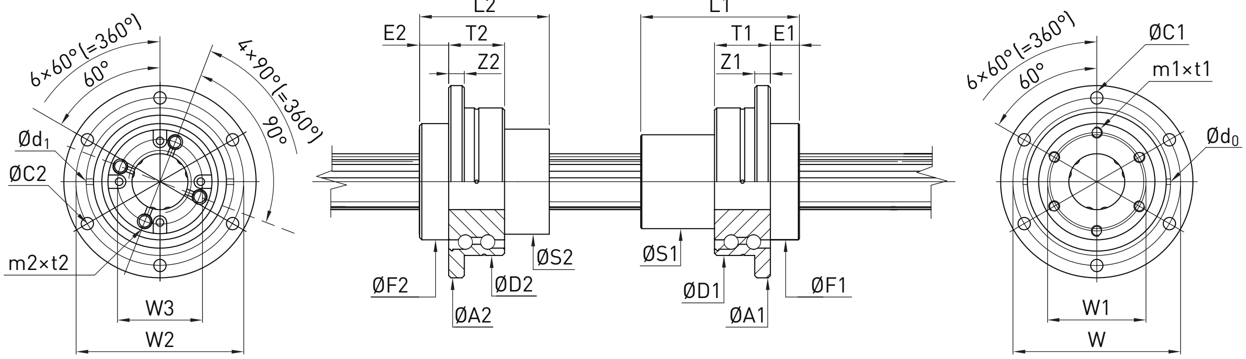


Table 8.2 **Product dimensions and specifications of nut type FB Ball Spline: ballscrew nut**

Series/ size	Specifications			Ballscrew nut															Outer ring basic rated load	
	Nominal shaft diameter	Nominal inner diameter	Lead	Basic rated load		Outer diameter D2 g6	Flange outer diameter A2	Total length L2	F2 h7	S2	T2	E2	Z2	W2	W3	m2 × t2	C2	Lubrication hole		
				C [kN]	C_0 [kN]													d_1	C_a [kN]	C_{0a} [kN]
16	16	11	16	4.7	9.6	48	64	40	36.0	32	21	10	6	56	25	M4 × 8	4.5	1.5	9.3	11.5
20	20	14	20	6.4	14.0	56	72	46	43.5	40	21	11	6	64	31	M5 × 8	4.5	1.5	9.8	13.5
25	25	18	25	9.5	21.9	66	86	58	52.0	47	25	13	7	75	38	M6 × 12	5.5	2.5	13.1	22.0
32	32	23	32	13.0	29.8	78	103	72	63.0	58	25	14	8	89	48	M6 × 10	6.6	2.5	13.7	25.2

All dimensions stated without a unit are in mm

Table 8.3 **Product dimensions and specifications of nut type FB Ball Spline: Ball Spline nut**

Series/ size	Ball spline nut																		Outer ring basic rated load	
	Basic rated load		Basic rated torsion		Allowable static torque	Outer diameter D1 g6	Flange diameter A1	Total length L1	F1 h7	S1	T1	E1	Z1	W	W1	m1 × t1	C1	Lubrication hole		
	C [kN]	C_0 [kN]	C_τ [Nm]	$C_{0\tau}$ [Nm]	MA [Nm]													d_0	C_a [kN]	C_{0a} [kN]
16	7.2	13.5	32.1	34.4	67.6	48	64	50	36.0	31	21	10	6	56	30	M4 × 6	4.5	1.5	9.3	11.5
20	10.4	20.0	57.8	63.2	118.0	56	72	63	43.5	35	21	12	6	64	36	M5 × 8	4.5	1.5	9.8	13.5
25	15.4	27.5	106.5	108.8	210.0	66	86	71	52.0	42	25	13	7	75	44	M5 × 8	5.5	2.5	13.1	22.0
32	20.5	34.4	181.5	173.1	290.0	78	103	80	63.0	52	25	17	8	89	54	M6 × 10	6.6	2.5	13.7	25.2

All dimensions stated without a unit are in mm

9. Options for Ball Spline

9.1 Lubrication

The lubrication varies depending on the conditions of use, but in general, the grease should be replenished at a running distance of 100 km (6 months–1 year). Lubricate the spline shaft by applying grease to the rolling groove or injecting grease into the nut lubrication hole, as shown in Fig. 9.1.

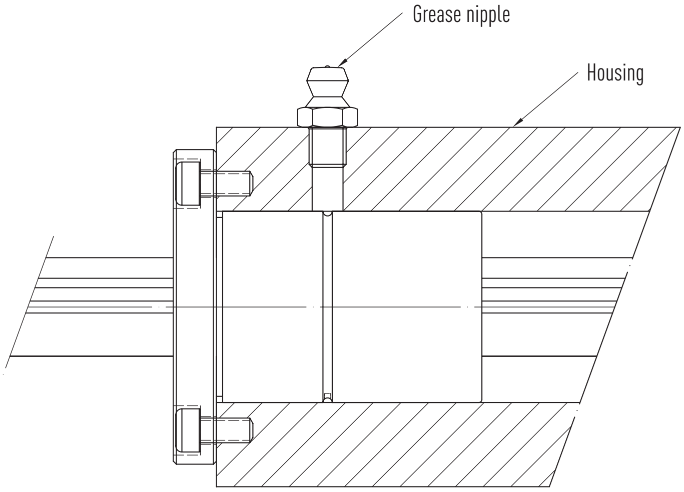


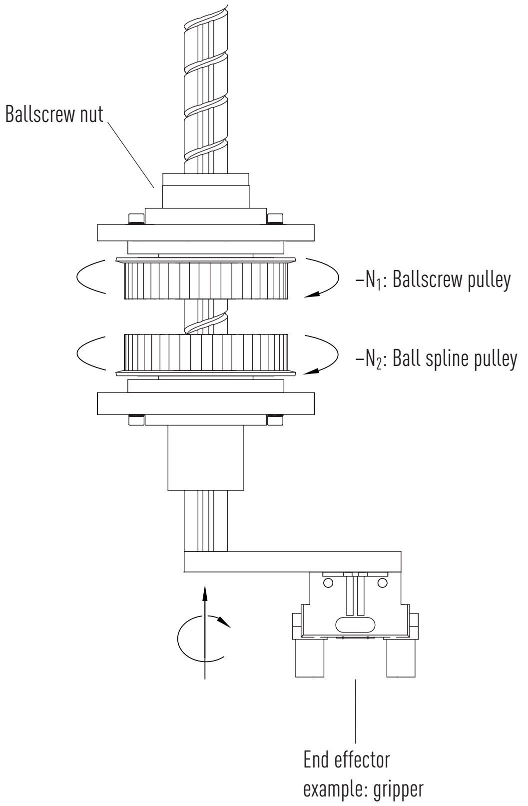
Fig. 9.1 **Lubrication method**

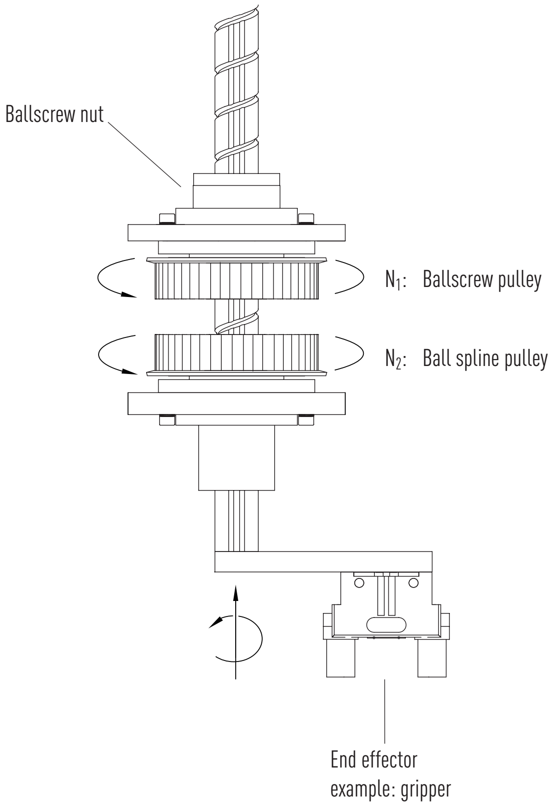
9.2 Material and surface treatment

Depending on the conditions of use, the Ball Spline may be treated for rust prevention or be manufactured with different material. Please contact HIWIN for the rust prevention treatment and change of material used.

10. Function of FB type Ball Spline

10.1 FB type Ball Spline working mode

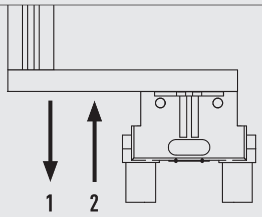
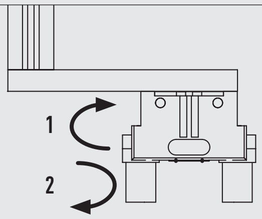
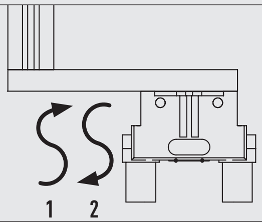




l_	Ballscrew lead [mm]
$-N_1$	Ballscrew pulley rotating speed (counter-clockwise) [min^{-1}]
$-N_2$	Ball spline pulley rotating speed (counter-clockwise) [min^{-1}]

l	Ballscrew lead [mm]
N_1	Ballscrew pulley rotating speed (clockwise) [min^{-1}]
N_2	Ball spline pulley rotating speed (clockwise) [min^{-1}]

Table 10.1 **Work modes for FB type Ball Spline**

Work mode		Motion direction	Input		Shaft motion	
			Ballscrew pulley	**Ball spline pulley**	**Vertical (speed)**	**Rotating direction (speed)**
	1	Vertical: downward Rotating direction: 0	N_1 $(N_1 \neq 0)$ (clockwise)	0	$V = N_1 \times l$	0
	2	Vertical: upward Rotating direction: 0	$-N_1$ $(-N_1 \neq 0)$ (counter-clockwise)	0	$V = -N_1 \times l$	0
	1	Vertical: 0 Rotating direction: clockwise	N_1 $(N_1 \neq 0)$ (clockwise)	N_2 $(N_2 \neq 0)$ (clockwise)	0	N_2 $(N_2 \neq 0)$ (clockwise)
	2	Vertical: 0 Rotating direction: counter-clockwise	$-N_1$ $(-N_1 \neq 0)$ (counter-clockwise)	$-N_2$ $(-N_2 \neq 0)$ (counter-clockwise)	0	$-N_2$ $(-N_2 \neq 0)$ (counter-clockwise)
	1	Vertical: downward Rotating direction: clockwise	0	N_2 $(N_2 \neq 0)$ (clockwise)	$V = N_2 \times l$	N_2 $(N_2 \neq 0)$ (clockwise)
	2	Vertical: upward Rotating direction: counter-clockwise	0	$-N_2$ $(-N_2 \neq 0)$ (counter-clockwise)	$V = -N_2 \times l$	$-N_2$ (counter-clockwise)

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Note:
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