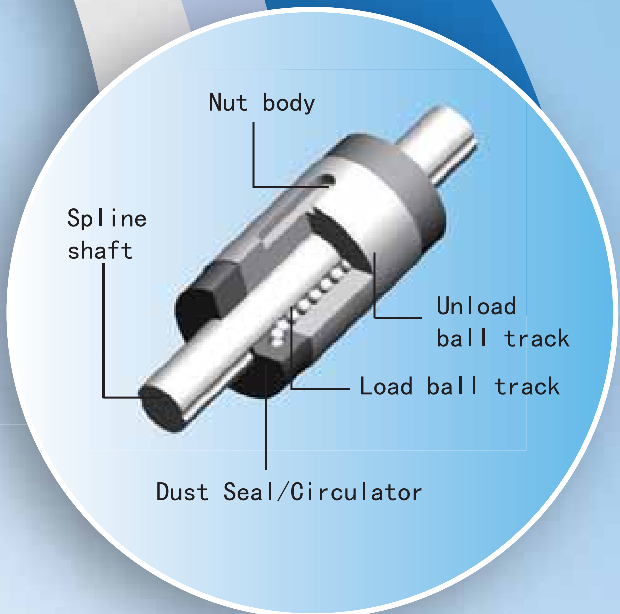
TBI MOTION



Ball Spline

TBI MOTION TECHNOLOGY CO.,LTD.

Innovative Power of Transmission Technology

Company Introduction

1986

Taiwan Ball Screw Industrial Co., Ltd. **(TBI)** was established in Tucheng Industrial District, Taipei, Taiwan. We were also the first manufacturer who produces ground type of precise ball screws in Taiwan.

TBI

1988

TBI established Research & Development Department and finished constructing the factory in Taichung that focuses on innovative product and producing precise grinding ball screw.

2002

COMTOP was established and exported ball screws to worldwide based on a professional and successful marketing sales system.

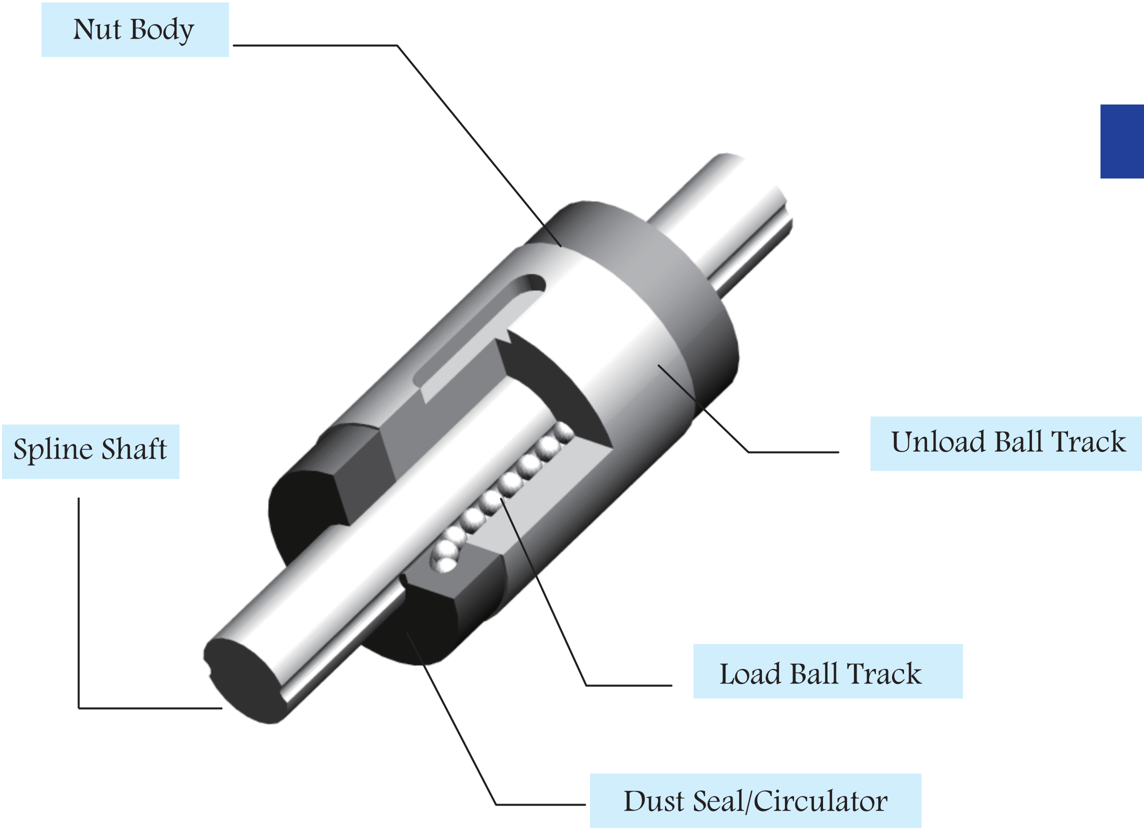
COMTOP

2010

TBI MOTION has integrated the technology of **TBI** and the marketing strategy of **COMTOP** to develop ***TBI MOTION*** that makes company in a leading place of Linear Motion Industry. The main products are Ball Screws, Linear Guides, Ball Splines, Linear Ball Bearing, Couplings, and Ball Screw Accessories ......etc.

TBI TBI MOTION

Ball Spline


Nut Body
Spline Shaft
Unload Ball Track
Load Ball Track
Dust Seal/Circulator

1. Construction of Ball Spline

The Ball Spline has balls accommodated in the spline nut transmit torque while linearly moving on precision-ground raceways on a spline shaft. Contact points are between the balls and raceways by ***TBI MOTION'S*** exclusive design, and the balls and raceway contact with each other over a wide range (40°). It performs high sensitivity and high load-carrying capability. As a result of this ability, Ball Spline is well suited for use under severe service conditions involving vibration and the application of impact loads, and in locations that require highly precise positioning and high-speed operation. When used in place of a linear bush, the Ball Spline can be provided with a compact design, as it has a load rating more than ten times greater than that of a linear bush with the same shaft diameter. Capable of withstanding overhanging loads and moments, the Ball Spline provides a high degree of safety and an extended service life.

TBI Ball Spline could refer to two different styles: SLF (with flange) and SLT (without flange). Base on different sizes of shaft diameter and contact point in raceway for the ball will develop two ranks (180°) (SLF6~20) and four ranks (70°) (SLF25~50). In addition, we also offer Hollow Spline Shaft for special request.

Feature

High Load-Carrying Capability

The raceway has to be formed by fine grinding procedure which requires 40° contact point of Gothic arch. The balls and raceway contact each other over a wide range; therefore, load-carrying capability in both the radial and torque-applying direction is great.

Zero Angular Backlash

The preloaded angular-contact design, in which two to four ranks of balls arranged opposite, hold a crest on the spline shaft at contact angle of 40°, reduces the angular backlash in the rotational direction to zero and increase rigidity.

High Sensitivity

Contact points are between the balls and raceways by special design. It performs the highest sensitivity and rigidity. It will also save more energy.

High Rigidity

A wide contact angle and an appropriate level off preload are combined to provide high torque and moment rigidity.

Simple Assembly

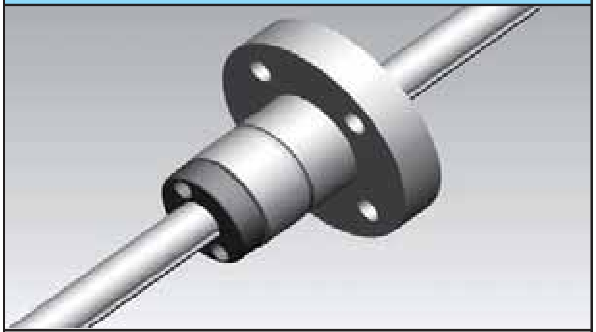
Even if it is necessary to remove the spline shaft due to special mounting conditions, the balls will not fall off by exclusive design. As a result, assembly, maintenance, and checking are simple to perform.

2. Classification of Ball Spline Type

Cylindrical Ball Spline Type SLT

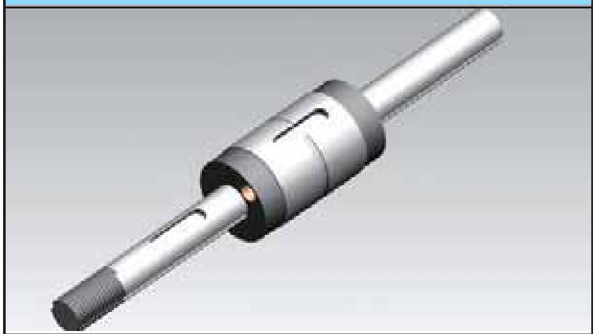
The spline nut is of a straight cylindrical shape. When it is necessary to apply a torque, insert a key into the keyway. Type SLT is the most compact of all Ball Spline types.

Flanged Ball Spline Type SLF



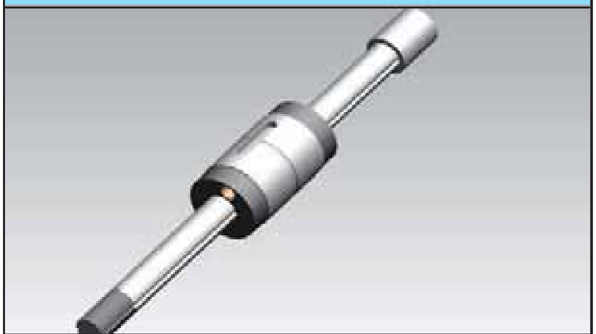
The spline nut can be attached to the housing via the flange, making assembly simple. It is most suitable where the housing may deform if a keyway is cut thereon, and where housing width is limited. Knock pins that can be driven into the flange completely eliminate the angular backlash that occurs in fitting part.

Precision Solid Spline Shaft (Stanard Type)



The spline shaft is formed by cold drawing, and the raceways are cut into the shaft to a high degree of precision. A spline nut is attached to the resulting spline shaft.

Special Spline Shaft

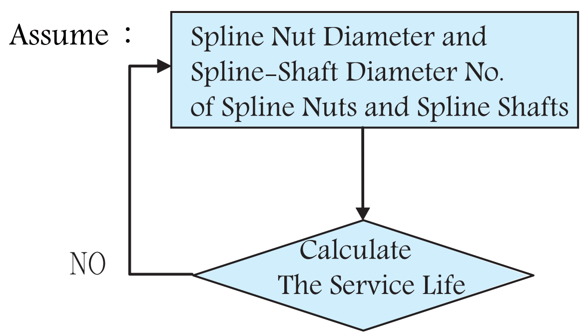


A shaft with a greater diameter at its ends or mid-point can be produced upon request, by machining it to the required spline shape.

Hollow Spline Shaft (Type H)

This type is made hollow through cold drawing. Enable it to accommodate pipes and vent air or to reduce its weight.

3. Procedure for Selecting the Optimum Type of Ball Spline

Procedure	Description
1. Set the Operating Conditions	○ Stroke Length：Ls ○ Velocity：V ○ Magnitude of The Applied Load：W ○ Installation Space ○ Rigidity ○ Frequency of Use (Duty Cycle) ○ Desired Service Life
2. Determine the Desired Type	○ See "Classification of Ball Spline Types."
3. Set the Spline-Shaft Strength	○ Assume a Spline-Shaft Diameter. ○ Assume a Spline-Shaft Length. ○ Determine the Spline-Shaft Fastening Method. ○ Determine the Spline-Shaft Permissible Load. ○ Obtain the Spline-Shaft Displacement (Deflection and Torsion)
4. Forecast the Service Life and Assume a Model No.	
5. Determine the Required Accuracy Grade	○ Spline Accuracy Grades
6. Design for Safety	○ Lubrication, Contamination Protection, and Precautions on Use

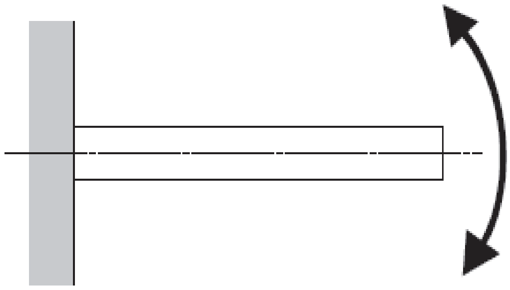
4. Design Spline-Shaft Strength

The spline shaft of the Ball Spline is a compound shaft capable of receiving a radial load and torque. When the load and torque are extraordinary, the spline-shaft strength must be taken into account.

4.1 Spline Shaft Subjected to a Bending Load

Base on assembly style, length of shaft, load condition to calculating maximum of bending moment (M). For Ball Spline shafts subjected to a bending load, determine the optimum spline-shaft diameter using (1) equation:

$$M = \sigma \cdot Z \qquad \text{or} \qquad Z = \frac{M}{\sigma} \quad \cdots\cdots\cdots \ (1)$$



M: Bending Moment

M: Maximum Bending Moment on the Shaft (N.mm)

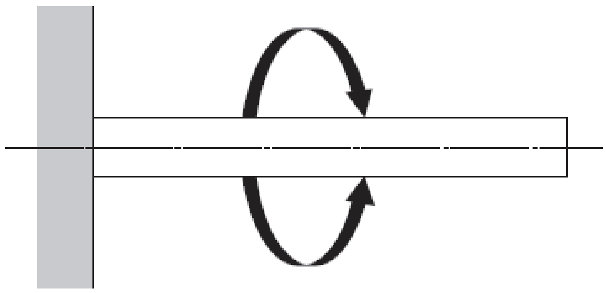
σ : Shaft Permissible Bending Stress (98 N / mm)

Z: Shaft section modulus (mm^3) See Table 3

4.2 Spline Shaft Subjected to Torsion

For spline shafts of the Ball Spline which are subjected to torsional load (T), determine the optimum spline-shaft diameter using equation(2):

$$T = \tau_a \cdot Z_P \qquad \text{or} \qquad Z_P = \frac{T}{\tau_a} \quad \cdots\cdots \ (2)$$



T: Torsion Moment

T: Maximum Torsion Moment (N.mm)

σ : Shaft Permissible Torsional Stress (49 N / mm)

Zp: Shaft Polar Section Modulus (mm^3) See Table 3

4.3 Spline Shaft Subjected to Both Torsion and a Bending Load Simultaneously

For Ball Spline spline shafts subjected to the simultaneous application of torsion and bending loads, calculate two separate spline-shaft diameters based on equation (3) and equation (4) to calculate the equivalent bending moment (Me) and the other for the equivalent torsion moment (Te). Take whichever is greater as the spline-shaft diameter.

Equivalent Bending Moment:

$$Me = \frac{M + \sqrt{M^2 + T^2}}{2} = \frac{M}{2}\left\{1 + \sqrt{1 + \left(\frac{T}{M}\right)^2}\right\} \quad \cdots\cdots\cdots \ (3)$$

$$Me = \sigma \cdot Z$$

Equivalent Torsion Moment:

$$Te = \sqrt{M^2 + T^2} = M \cdot \sqrt{1 + \left(\frac{T}{M}\right)^2} \quad \cdots\cdots\cdots \ (4)$$

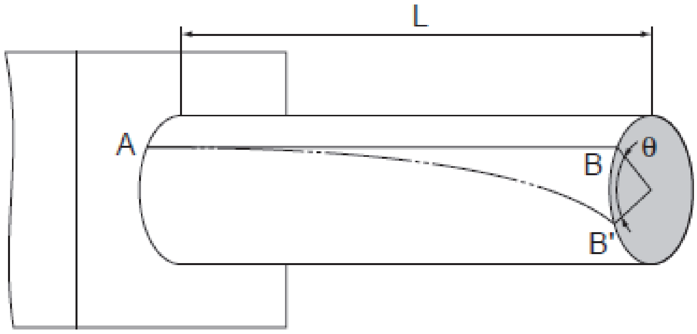
$$Te = \tau_a \cdot Z_P$$

4.4 Rigidity of the Spline Shaft

The rigidity of the Spline Shaft is expressed as a torsion angle per meter of shaft length. This should be limited to a maximum of approximately 1/4°.

$$\theta = 57.3 \times \frac{T \cdot L}{G \cdot I_p} \quad \cdots\cdots\cdots \quad (5)$$

$$\text{Shaft Rigidity} = \frac{\text{Torsion Angle}}{\text{Unit Length}} = \frac{\theta}{\ell} < \frac{1^\circ}{4}$$



where

- θ : Torsion Angle (°)
- L : Shaft Length (mm)
- G : Transverse Elastic Modulus ($G = 7.9 \times 10^4 N/mm^2$)
- ℓ : Unit Length (1000mm)
- I_p : Polar Moment of Inertia I_p (mm^4)
  See Tables 3 and 4

4.5 Deflection and Deflection Angle of the Spline Shaft

These should be calculated using equations satisfying the relevant operating conditions. Tables 1 and 2 present the operating conditions and the corresponding equations.

Tables 3 presents the cross-section factors (Z) and cross-section secondary moments (I). Through the use of the Z and I values given in these tables, the strength and degree of displacement (deflection) of each Ball Spline model in general use can be determined.

Table 1 Deflection and Deflection-Angle Equation

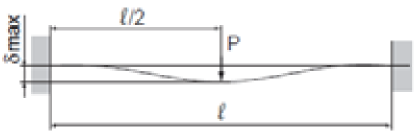
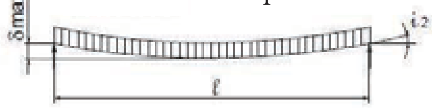
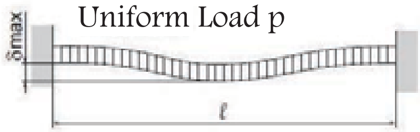
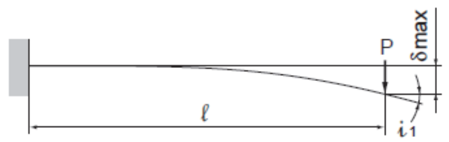
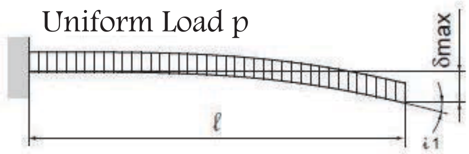
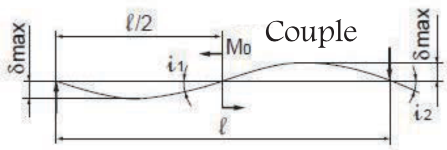
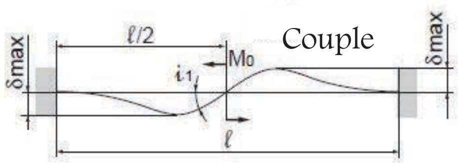
Support Method	Specification Conditions	Deflection Equation	Deflection-Angle Equation
Both Ends Free		$\delta_{max} = \dfrac{P\ell^3}{48EI}$	$i_1 = 0$ $i_2 = \dfrac{P\ell^2}{16EI}$
Both Ends Fastened		$\delta_{max} = \dfrac{P\ell^3}{192EI}$	$i_1 = 0$ $i_2 = 0$
Both Ends Free	Uniform Load p 	$\delta_{max} = \dfrac{5p\ell^4}{384EI}$	$i_2 = \dfrac{P\ell^3}{24EI}$
Both Ends Fastened	Uniform Load p 	$\delta_{max} = \dfrac{p\ell^4}{384EI}$	$i_2 = 0$

Table 2 Deflection and Deflection-Angle Equation

Support Method	Specification Conditions	Deflection Equation	Deflection-Angle Equation
One End Free		$\delta_{max} = \frac{P\ell^3}{3EI}$	$i_1 = \frac{P\ell^2}{2EI}$ $i_2 = 0$
One End Fastened		$\delta_{max} = \frac{p\ell^4}{8EI}$	$i_1 = \frac{p\ell^3}{6EI}$ $i_2 = 0$
Both Ends Free		$\delta_{max} = \frac{\sqrt{3}M_0\ell^2}{216EI}$	$i_1 = \frac{M_0\ell}{12EI}$ $i_2 = \frac{M_0\ell}{24EI}$
Both Ends Fastened		$\delta_{max} = \frac{M_0\ell^2}{216EI}$	$i_1 = \frac{M_0\ell}{16EI}$ $i_2 = 0$

δ_{max} : Maximum Deflection (mm)

i_1 : Deflection Angle at a Loading Point (deg)

i_2 : Deflection Angle at a Supporting Point (deg)

M_0 : Moment (N・mm)

P : Concentrated Load (N)

p : Uniform Load (N/mm)

ℓ : Span (mm)

I : Geometrical Moment of Inertia (mm^4)

E : Longitudinal Elastic Modulus ($2.06x10^5$ N/mm^2)

4.6 Critical Speed of Spline Shaft

With Ball Spline spline shafts used for power transmission, as the shaft speed increases, the frequency of vibration nears the proper value for the shaft, eventually causing resonance making motion impossible. The maximum shaft speed must therefore be set at a level that does not cause resonance. The critical speed of the spline shaft is determined using the equation given below. The obtained value should be multiplied by a safety factor of 0.8.

Permissible Rotational Frequency

$$Nc=\frac{60\lambda^2}{2\pi\cdot\ell_b}\cdot\sqrt{\frac{E\times10^3\cdot I}{\gamma\cdot A}}\times0.8 \quad \cdots\cdots\cdots \quad (6)$$

Nc : Critical Shaft Speed (min^{-1})

ℓ_b : Center Distance (mm)

E : Young's Modulus $(2.06\times10^5 N/mm^2)$

I : Minimum Geometrical Moment of Inertia of the Shaft (mm^4)

$I=\frac{\pi}{64}d_1^4$ d_1: Minor Diameter(mm)

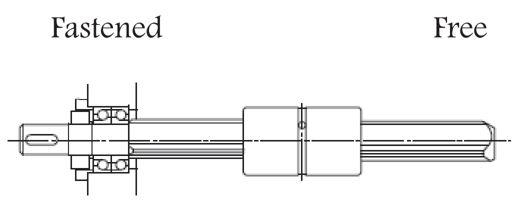
γ : Density (Specific Gravity; $7.85\text{X}10^{-6} kg/mm^3$)

$A=\frac{\pi}{4}d_1^2$ d_1: Minor Diameter(mm)

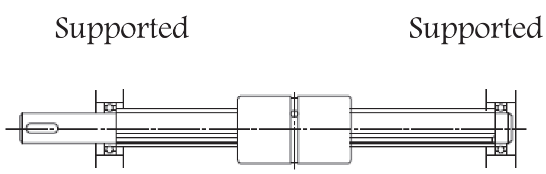
A : Spline-Shaft Cross-Sectional Area (mm^2)

λ : Installation-Method-Dependent Factor

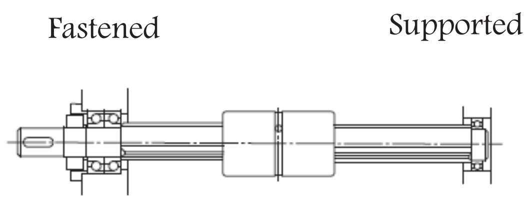
① Fastened/ Free: $\lambda=1.875$
② Supported/ Supported: $\lambda=3.142$
③ Fastened/ Supported: $\lambda=3.927$
④ Fastened/ Fastened: $\lambda=4.730$



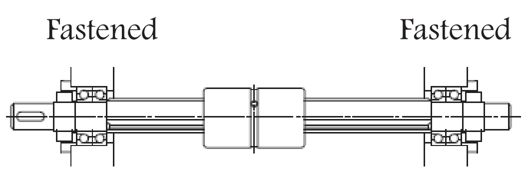
Fastened-Free



Supported-Supported



Fastened-Supported



Fastened-Fastened

4.7 Spline-Shaft Cross-Sectional Characteristics

Table 3

Nominal Shaft Diameter		I (mm⁴)	I_p (mm⁴)	Z (mm³)	Z_p (mm³)
SLF 6	Solid Shaft	58.36	121.93	19.45	40.64
SLF 8	Solid Shaft	191.57	392.58	47.89	98.15
SLF 10	Solid Shaft	460.28	950.92	92.06	190.18
SLF 13	Solid Shaft	1331.59	2733.15	204.68	420.49
SLF 16	Solid Shaft	3125.93	6251.33	390.68	781.42
SLF 20	Solid Shaft	7681.10	15361.41	768.03	1536.14
SLF 25	Solid Shaft	18801.16	37600.75	1503.97	3008.06
SLF 30	Solid Shaft	39173.80	78345.79	2611.47	5223.05
SLF 40	Solid Shaft	122980.03	245947.88	6148.39	12297.39
SLF 50	Solid Shaft	301648.34	603278.19	12065.19	24131.13

I : Geometrical moment of inertia (mm^4)

I_P : Polar moment of inertia (mm^4)

Z : Section modulus (mm^3)

Z_P : Polar section modulus (mm^3)

5. Forecasting Service Life

5.1 Nominal Life

The Ball Spline service life varies greatly from piece to piece, even if they are manufactured to the same specifications and remain in service under the same operating conditions.
Therefore, guidelines for determining the service life of a linear-motion system are given based on the nominal life defined below.

"Nominal Life" refers to the total running distance that 90% of identical linear-motion systems in a group, when interlocked with one another under the same conditions, can achieve without developing flaking.

5.2 Calculating Nominal Life

The Ball Spline nominal life varies for the three modes of load: torque, radial load, and moment. As the basic load ratings under these loads are presented in the corresponding dimension tables, the nominal life under a respective load can be determined using equations (7) to (10).

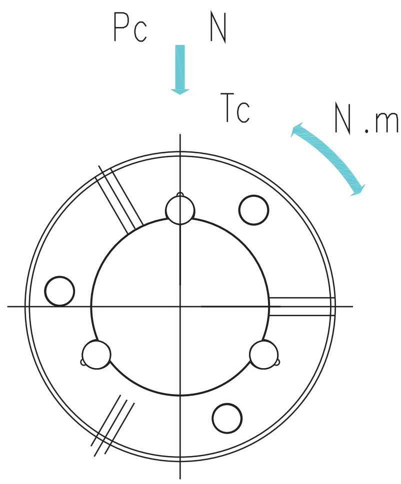
Under a Torque Load

$$L = \left(\frac{f_T \cdot f_C}{f_w} \cdot \frac{C_T}{T_c} \right)^3 \times 50 \quad \cdots\cdots\cdots \quad (7)$$

Under a Radial Load

$$L = \left(\frac{f_T \cdot f_C}{f_W} \cdot \frac{C}{P_c} \right)^3 \times 50 \quad \cdots\cdots\cdots \quad (8)$$

L	:	Nominal Life	(km)
C_T	:	Basic Dynamic-Torque Rating	(N.m)
T_C	:	Calculated Torque Applied	(N.m)
C	:	Basic Dynamic-Load Rating	(N)
P_C	:	Calculated Radial Load	(N)
f_T	:	Temperature Factor (See Fig. 2)	
f_C	:	Contact Factor (See Table 4)	
f_W	:	Load Factor (See Table 5)	



Under both a torque and radial load applied simultaneously

In this case, calculate the equivalent radial load to determine service life by equation(9)

$$P_E = P_C + \frac{4 \cdot T_C \times 10^3}{i \cdot dp \cdot \cos\alpha} \quad \cdots\cdots\cdots \quad (9)$$

P_E	:	Equivalent Radial Load (N)
$\cos\alpha$	:	Contact Angle
i	:	Number of Loaded Rows of Balls
dp	:	Ball Center-to-Center Shaft Diameter (mm)

Under a moment on one spline nut or two closely linked to one another

Obtain the equivalent radial load using the equation, and determine the service life by equation(10)

$$P_U = K \cdot M \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (10)$$

P_U	:	Equivalent Radial Load (Moment Applied)
K	:	Equivalent Factor (See Tables 7 and 8)
M	:	Applied Moment (N.mm)

However, M should be within the range of the static permissible moment.

Calculating Nominal Life

Once the nominal life (L) is obtained as specified above, if the stroke length and the number of reciprocal operations are constant, the service life in hours is obtained using the following equation

$$L_h = \frac{L \times 10^3}{2 \times \ell_S \times n_1 \times 60} \quad \cdots\cdots\cdots \quad (11)$$

L_h : Service Life in Hours (h) ℓ_S : Stroke Length (m)
n_1 : Number of Reciprocal Operations Per Minute (opm)

f_T: Temperature Factor

When the Ball Spline is used in an environment at a temperature of 100℃ or higher, the heat may adversely affect the operation of the Ball Spline. In the event of such an effect, one of the temperature factors specified Fig. 2 should be multiplied to by a service-life value. In addition, make sure the Ball Spline itself has high-temperature specifications.

Note: Where the ambient temperature exceeds 80℃, the materials of seals and retainers should be changed to those with high-temperature specifications.

Fc: Contact Factor

When multiple spline nuts are used closely linked to one another, their linear motion is affected by moments and mounting accuracy, resulting in nonuniform load distribution. When closely linked spline nuts are used, multiply the basic load rating (C or C_0) by one of the contact factors specified below.

Note: if a non-uniform load distribution is expected, as in large equipment, take the contact factor explained in Table 4 into account.

fw: Load Factor

In general, the operation of reciprocal machines is likely to involve vibration and impact. In the event of vibration occurring during high-speed operation and repeated impact during start and stop, it is very difficult to accurately determine their magnitudes. Therefore, when loads exerted on a linear-motion system which cannot be determined or when the effect of velocity and vibration is extraordinary, divide the basic load rating (C or C_0) by one of the empirically established load factors given in Table 5.

Under Both a Moment and Radial Load Applied Simultaneously

Calculate the service life from the sum of the radial load and the equivalent radial load.

Fig. 2 Temperature factor (ft)

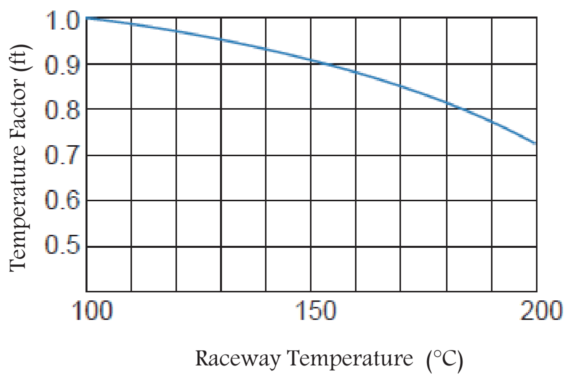


Table 4 Contact Factor (fc)

No. of Spline nuts Linked	f_C
2	0.81
3	0.72
4	0.66
5	0.61
In Normal Use	1.0

Table 5. Load Factor (f_W)

Vibration and Impact	Velocity (V)	f_W
Very Light	Very Low: V≦0.25 m/s	1-1.2
Light	Low: 0.25<V≦1.0 m/s	1.2-1.5
Medium	Intermediate: 1.0<V≦2.0 m/s	1.5-2.0
Heavy	High: V>2.0 m/s	2.0-3.5

5.3 Calculating the Mean Load

Load maybe changed while the Ball Spline is in operation. An industrial robot grabs a work with its arm as it advances, then moves on under a load. When it returns, the arm has no load other then its tare. In a machine tool, the spline nut of the Ball Spline receives varying loads, depending on the host- system operating conditions. The service life of the Ball Spline should therefore be calculated in consideration of such fluctuations in load.

The mean load (Pm) is the load under which the service life of the Ball Spline becomes equivalent to that under varying loads exerted on the spline nut while in operation.

The Equation is as below:

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

P_m : Mean Load (N)

P_n : Fluctuating Load (N)

L : Total Running Distance (mm)

Ln : Running Distance Under Load Pn (mm)

For Loads That Change Stepwise

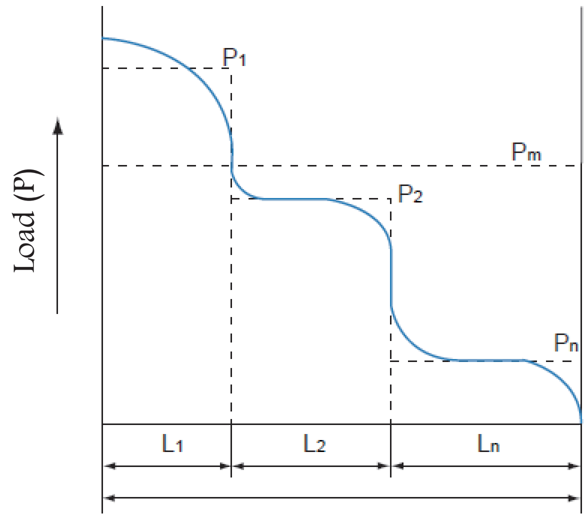
$$P_m=\sqrt[3]{\frac{1}{L}(P_1^3\cdot L_1+P_2^3\cdot L_2....+P_n^3\cdot L_n)}$$

Pm : Mean Load (N)

Pn : Fluctuating Load (N)

L : Total Running Distance (m)

Ln : Running Distance Under Load Pn (m)

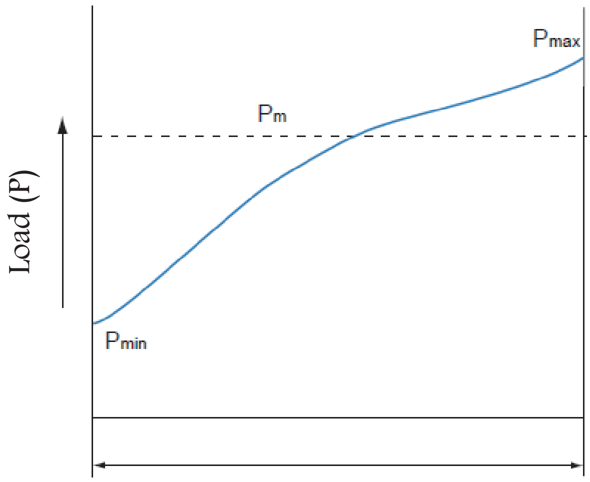


For Loads That Change Monotonically

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

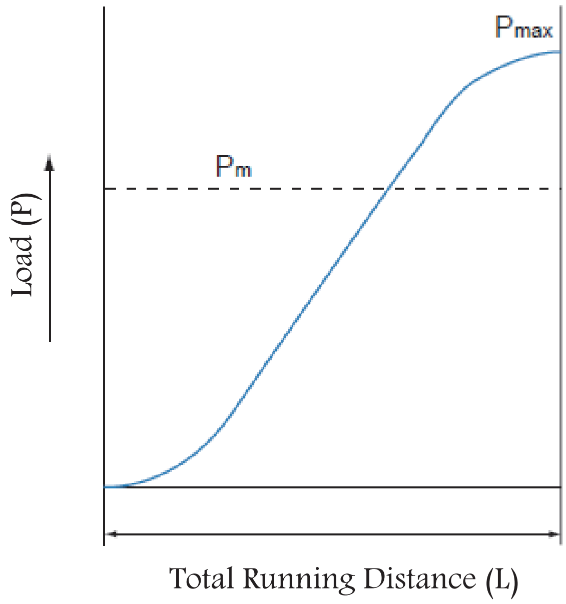
Pmin : Minimum Load (N)

Pmax : Maximum Load (N)

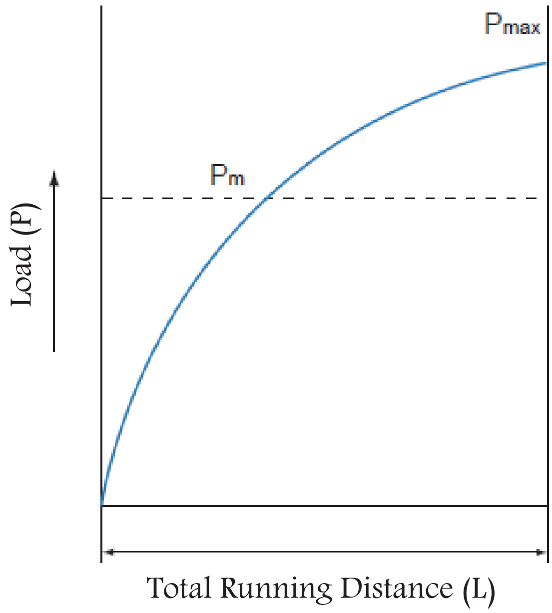


For Loads That Change Sinusoidally

(a) $P_m \fallingdotseq 0.65P_{max}$



(b) $P_m \fallingdotseq 0.75P_{max}$



5.4 Equivalent Factor

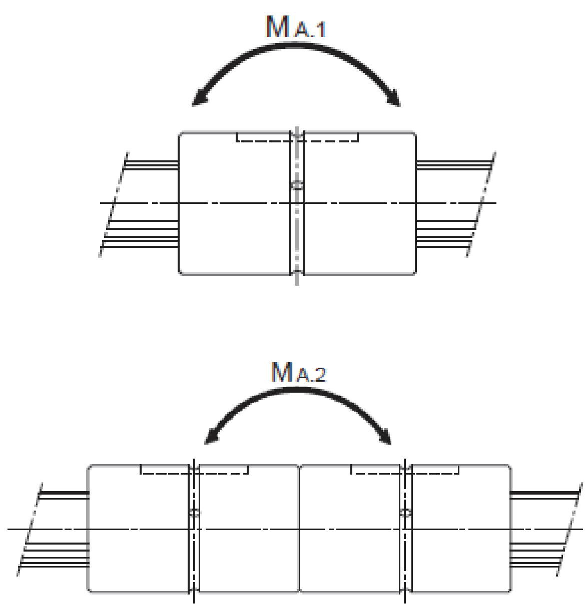


Table 7

Model No.	Single Spline Nut	Closely Linked Double Spline Nuts
SLF 06	0.434	0.055
SLF 08	0.434	0.055
SLF 10	0.375	0.047
SLF 12	0.326	0.043
SLF 13	0.211	0.032
SLF 20	0.181	0.028
SLF 25	0.142	0.022
SLF 30	0.118	0.020
SLF 40	0.104	0.016
SLF 50	0.079	0.013

6. Determining the Preload Level

A preload on the Ball Spline has a significant effect on accuracy, load resistance, and rigidity. Therefore, it is very important to determine the most appropriate size of the clearance for your purpose of use. The size of the clearance is standardized for each type, enabling the one best - suited for operating conditions to be selected.

6.1 Clearance in the Rotational Direction

With the Ball Spline, the sum of clearances in the circumferential direction is standardized as the clearance in the rotational direction.

Clearance in the Rotational Direction (BCD)

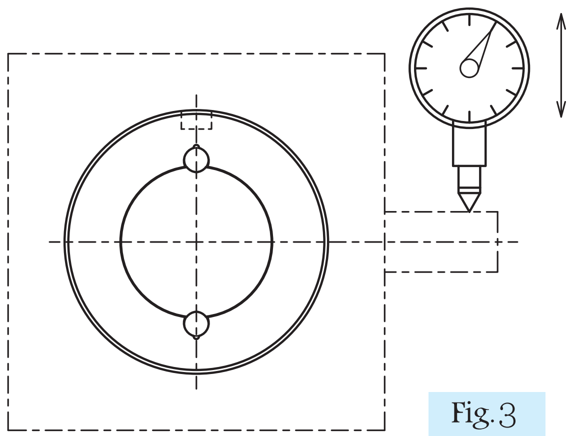


Fig.3

6.2 Preload and Rigidity

The preload is the load applied to balls prior to use for the purposes of eliminating angular backlash (clearance in the rotational direction) and improving rigidity. The application of a preload can eliminate angular backlash in the Ball Spline in accordance with the level of applied preload , and can improve rigidity. Fig.4 shows the amount of displacement in the rotational direction when a rotational torque is applied. As shown, the effect of preloading continues until the torque becomes 2.8 times greater than the preload applied. Compared with a setting without a preload, displacement at the same rotational torque is half that under a preload orless, and the rigidity is twice as great.

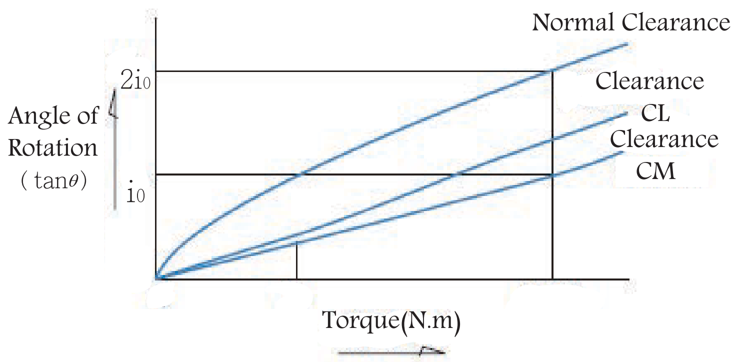


Fig. 4

6.3 Operating Conditions and Determination of the Preload Level

Table 8 presents guidelines for determining the appropriate clearance in the rotational direction for the given Ball Spline operating conditions. The rotational clearance of the Ball Spline significantly affects the accuracy and rigidity of the spline nut. Therefore it is critical to select the clearance best suited for the intended uses of the Ball Spline. Normally, the Ball Spline in use is preloaded. When it is subjected to repeated swiveling and reciprocal linear motion, a system receives heavy vibration and impact. In such an environment, preloading prolongs the service life and improves accuracy.

Table 8. Guidelines for Determining an Appropriate Ball-Spline Clearance in the Rotational Direction.

	Preload	Operating conditions	Sample conditions
Clearance in the Rotational Direction	Medium Preload P2	• High rigidity is required. Vibration and impact are severe. • The moment load must be borne by a single spline nut.	Construction-work-vehicle steering shaft; spot-welding-machine shaft; automatic-lathe-tool rest indexing shaft.
	Slight Preload P1	• Overhang loads and moments are applied. • Highly reproducible accuracy is required. • Alternate loads are applied.	Industrial robot arm; various automatic loaders; automatic-painting-machine guide shaft; electric-discharge-machine spindle; press die-set guide shaft; drilling-machine spindle.
	Normal P0	• Smooth movement should be achieved with only a low magnitude of force. • Torque is continually applied in a given direction	Various measuring instruments; automatic drafting machine; shape-measuring instrument; dynamometer; wire winder; automatic arc cutter; honing-machine spindle; automatic packing machine.

Table 9. SLT and SLF Clearance in the Rotational Direction

Unit: μm

Nominal Shaft Diameter \ Preload				Normal P0	Slight Preload P1	Medium Preload P2
6	8	10	13	−2 ~ + 1	−6 ~ −2	-
16		20		−2 ~ + 1	−6 ~ −2	−9 ~−5
25		30		−3 ~ + 2	−10 ~ −4	−14 ~−8
40		50		−4 ~ + 2	−16~ −8	−22 ~−14

7. Design for Accuracy

7.1 Accuracy Grade

The accuracy of the Ball Spline is divided into three grades-normal (N), high (H) , and precision (P)-according to the runout of the spline-nut outer diameter in relation to the supporting portion of the spline shaft.

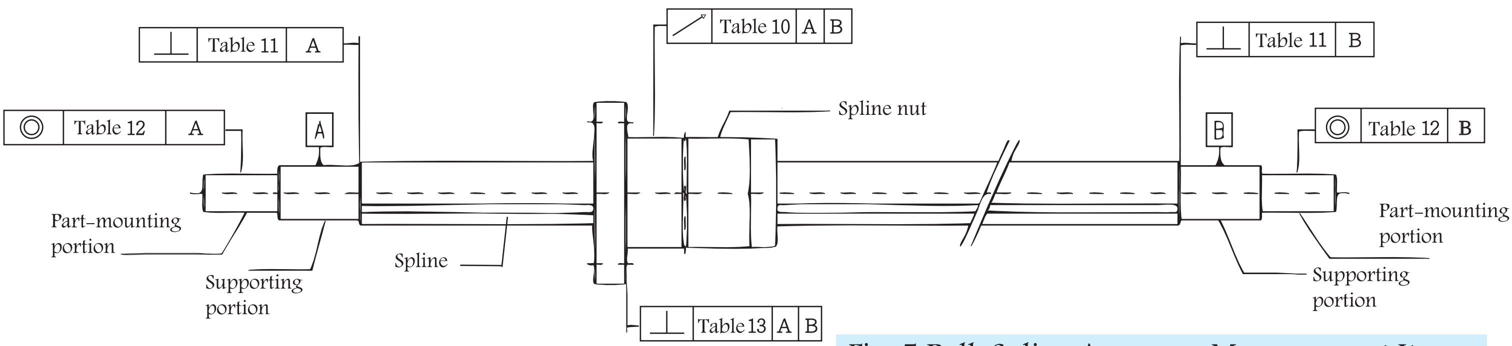


Fig. 5 Ball-Spline Accuracy Measurement Items

7.2 Accuracy Standards

Tables 10 through 13 present the measurement items of the Ball Spline

Table 10 Runout of the Spline-Nut Diameter in Relation to the Spline-Shaft Supporting Portion.

Unit : μm

Spline Overall Length(mm) \ Nominal Shaft Diameter		8			10			13,16,20			25,30			40,50		
Over	To (incl.)	Normal	High	Precision	Normal	High	Precision	Normal	High	Precision	Normal	High	Precision	Normal	High	Precision
-	200	72	46	26	59	36	20	56	34	18	53	32	18	53	32	16
200	315	133	89	57	83	54	32	71	45	25	58	39	21	58	36	19
315	400	185	126	82	103	68	41	83	53	31	70	44	25	63	39	21
400	500	236	163	108	123	82	51	95	62	38	78	50	29	68	43	24
500	630	-	-	-	151	102	65	112	-	-	88	57	34	74	47	27
630	800	-	-	-	190	130	85	-	-	-	103	68	42	84	54	32

Table 11 Perpendicularity of the Spline-Shaft End Face in Relation to the Spline-Shaft Supporting Portion (Maximum Accuracy Grade)

Unit: μm

Nominal Shaft Diameter \ Accuracy			Normal (N)	High (H)	Precision (P)
6	8	10	22	9	6
13	16	20	27	11	8
25	30		33	13	9
40	50		39	16	11

Table 12 Concentricity of the Part-Mounting Portion in Relation to the Spline-Shaft Supporting Portion. (Maximum Accuracy Grade)

Unit : μm

Nominal Shaft Diameter \ Accuracy			Normal (N)	High (H)	Precision (P)
6	8		33	14	8
10			41	17	10
13	16	20	46	19	12
25	30		53	22	13
40	50		62	25	15

Table 13 Perpendicularity of the Spline-Nut Flange-Mounting Surface in Relation to the Spline-Shaft Supporting Portion. (Maximum Accuracy Grade)

Unit : μm

Nominal Shaft Diameter \ Accuracy				Normal (N)	High (H)	Precision (P)
6	8			17	11	8
10	13			33	13	9
16	20	25	30	30	16	11
40	50			46	19	13

Table 14 Available Length for Accuracy Grade

Unit : μm

Accuracy Grade	Normal (N)	High (H)	Precision (P)
Acceptable Range	33	13	6

Note: Apply for any spline shaft for100mm operative

8. Assembly and Installation

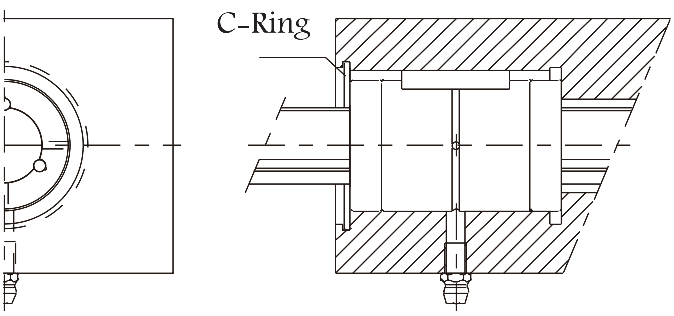
8.1 Housing Inner-Diameter Tolerance

The fit between the spline nut and the housing is normally a stop fit. When high accuracy is not required of the Ball Spline, a clearance fit is used.

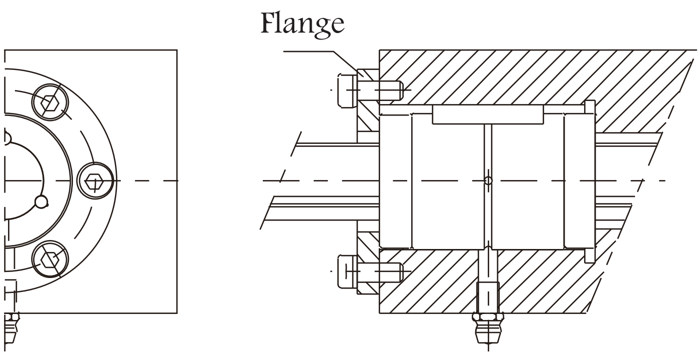
Applied Part	Housing Inner -Diameter Tolerance
Normal Operating Conditions	H7
When No Clearance is Permissible	J6

8.2 Assembling the Spline Nut

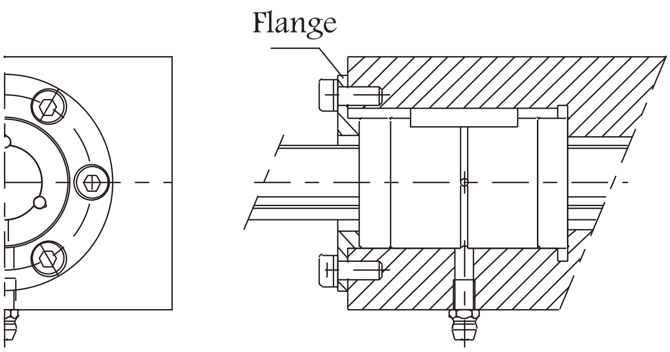
Figs. 6 and 7 show a sample of spline-nut assembly. While it is not necessary for the fastening strength in the axial direction to be very high, do not rely on a drive fit alone.



C-Ring Type



Plain Surface Type (Flange)



Two-Stage Type (Flange)

Fig. 6 Sample of Spline-Nut Assembly

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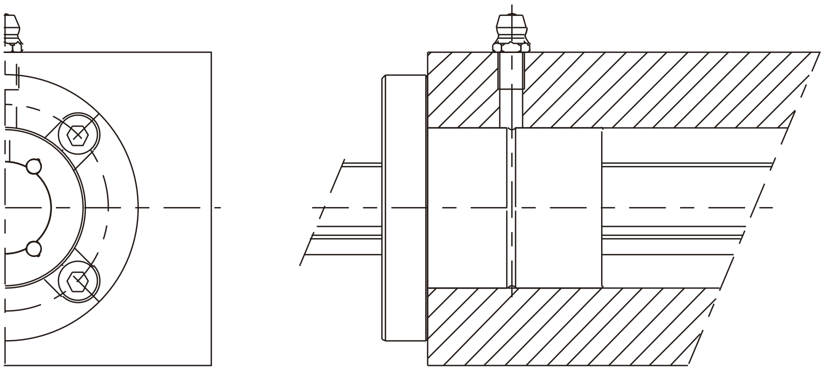
Ball Spline

Fig. 7 Sample of Spline-Nut Assembly



One-Piece Type (Flange)

8.3 Assembling the Spline Nut

When inserting a spline nut into a housing, drive it in gently by using a jig (Fig. 8) so as not to strike the side plates or seals.

Fig. 8

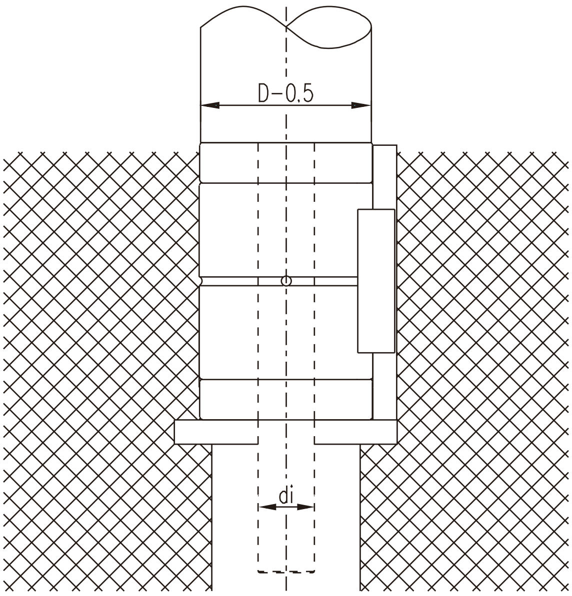


Table 16 Type-SLT Jig Dimensions

Unit: μm

Nominal Shaft Diameter	6	8	10	13	16	20	25	30	40	50
di	5.0	7.0	8.5	11.5	14.5	18.5	23	28	37.5	46.5

8.4 Model-Number Coding

SLF 006 T2 N N S - 500 - P0 - B2

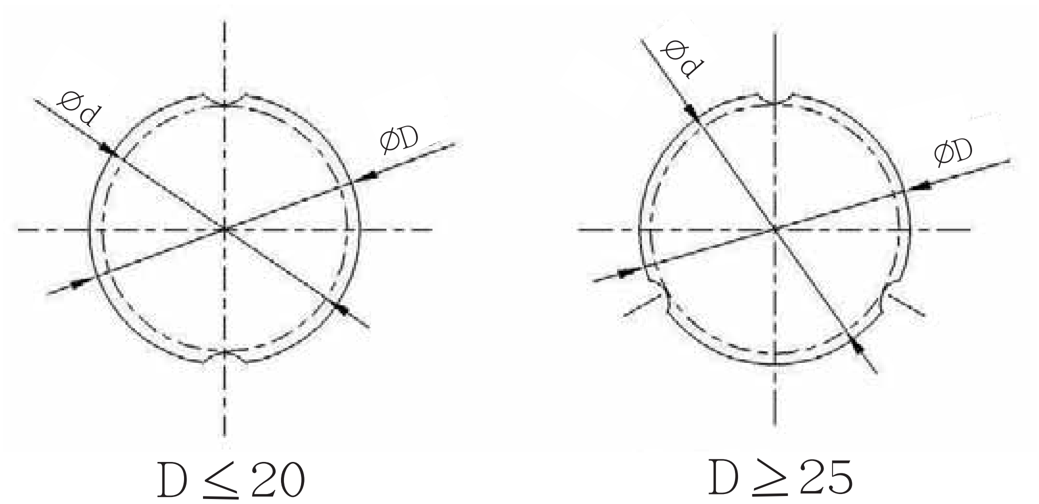
(1) (2) (3) (4) (5) (6) (7) (8) (9)

(1)	Spline Nut	SLF: Flange Type SLT: Cylindrical Type
(2)	Shaft Diameter	Unit: mm
(3)	No. of Trains	T2: Two Trains T4: Four Trains
(4)	Type of Flange	N: No Cutting (Round) S: Single Cutting D: Double Cutting (No Symbol When It is Without the Flange)
(5)	Accuracy Grade	N: Normal Grade H: High Grade P: Precision Grade
(6)	Type of Spline Shaft	S: Solid Spline Shaft H: Hollow Spline Shaft
(7)	Length of Spline Shaft	Unit: mm
(8)	Preload	P0: Zero Preload P1: Slight Preload P2: Medium Preload
(9)	Number of Nuts	(No Symbol When It is One) E.g. Two Nuts : B_2

9. Spline Shaft

9.1 Solid Spline Shaft Cross-Sectional Shape

Table (16) and (17) present Solid Spline Shaft cross-sectional shape and Hollow Spline-Shaft cross-sectional shape. If only, rework shaft ends to a cylindrical shaft, limit the diameter to minor diameter (∅d) or less.



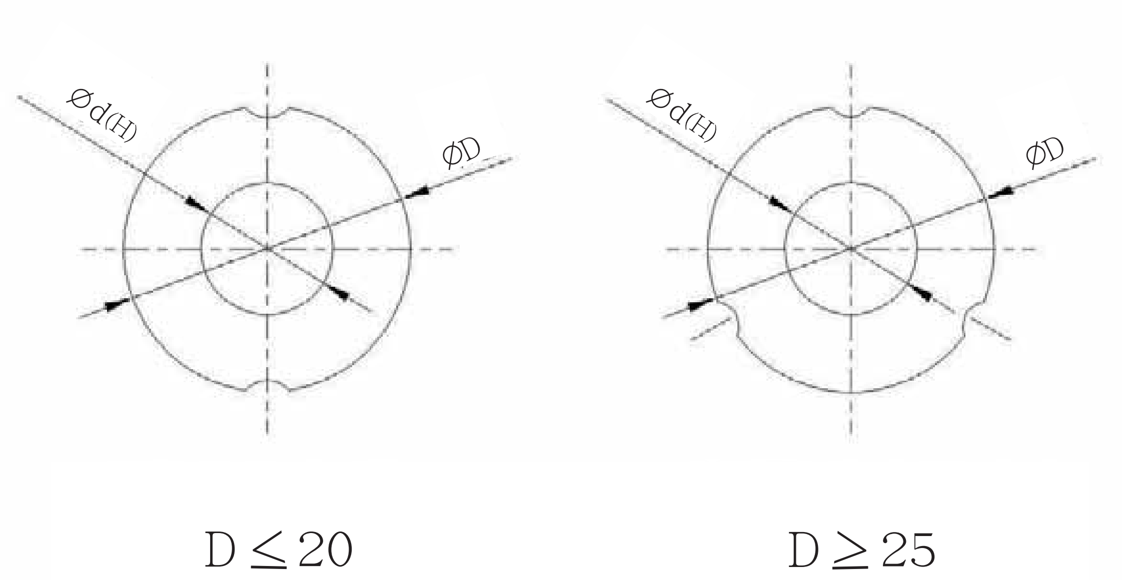
Solid Spline Shaft

Table 16 Solid Spline Shaft Cross-Sectional Shape

Unit : mm

Nominal Shaft Diameter / Data	6	8	10	13	16	20	25	30	40	50
Minor Diameter ∅d	5.25	7.27	8.97	11.82	14.72	18.63	23.43	28.53	37.3	47.05
Outer Diameter ∅D h7	6	8	10	13	16	20	25	30	40	50
Mass (kg/m)	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25

9.2 Hollow Spline Shaft Cross-Sectional Shape



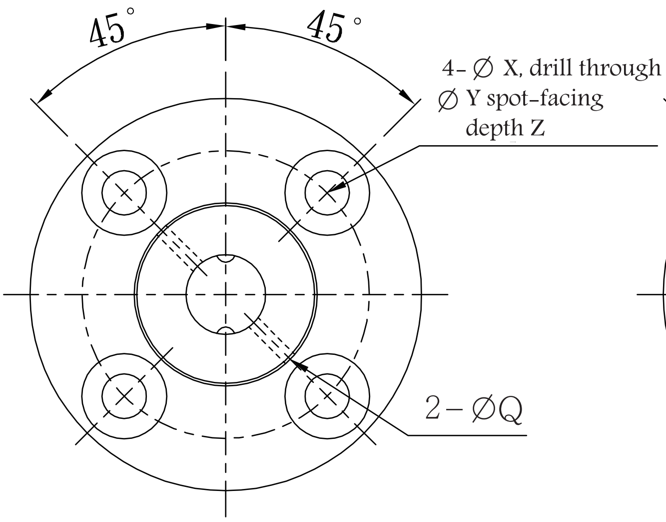
Hollow Spline Shaft

Table 17 Hollow Spline Shaft Cross-Sectional Shape

Unit：mm

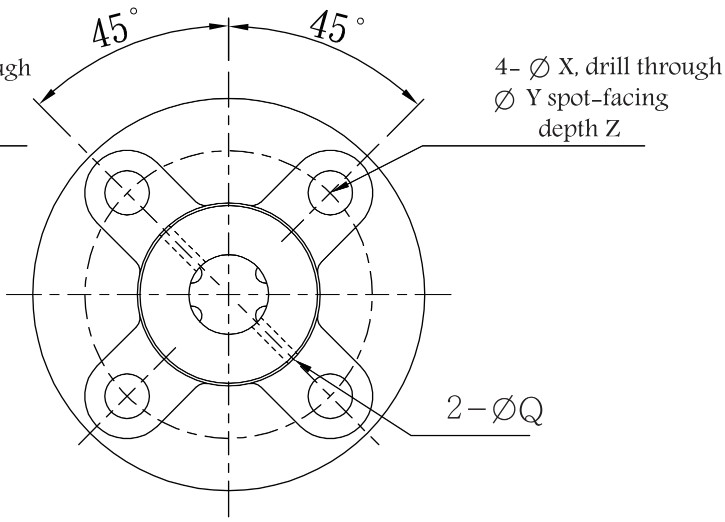
Nominal Shaft Diameter / Data	6	8	10	13	16	20	25	30	40	50
Hollow Diameter ϕd	2	3	4	7	8	10	15	16	20	26
Outer Diameter ϕD h7	6	8	10	13	16	20	25	30	40	50
Mass kg/m)	0.177	0.33	0.506	0.872	1.25	1.82	2.92	3.93	6.75	11.4

(Type: SLF)



SLF 20 or Lower

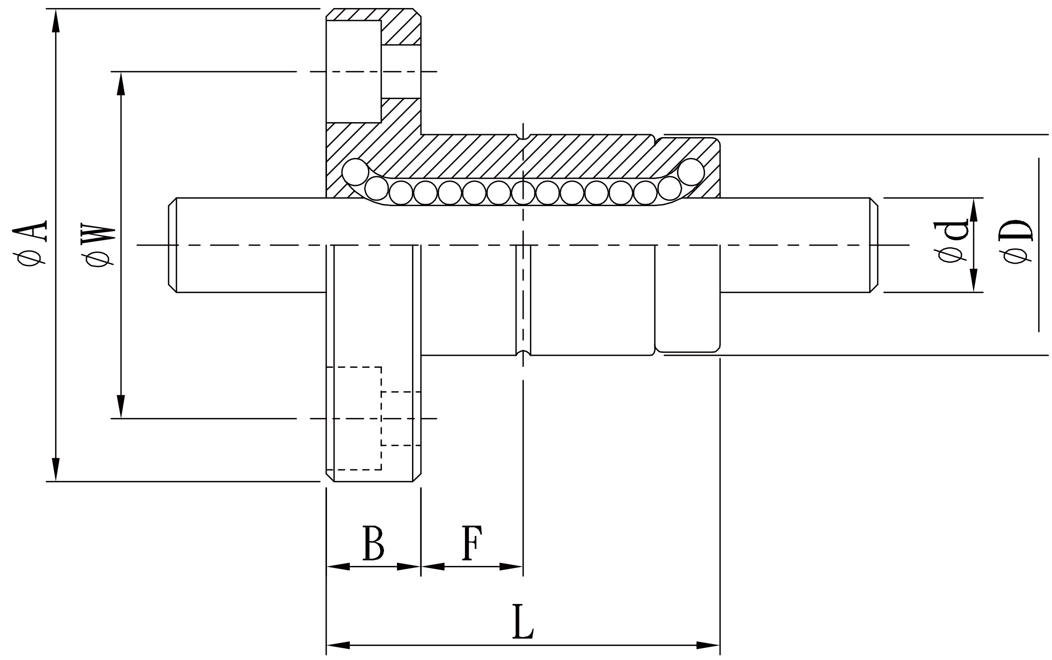
(Two Trains of Balls)



SLF 25 or Higher

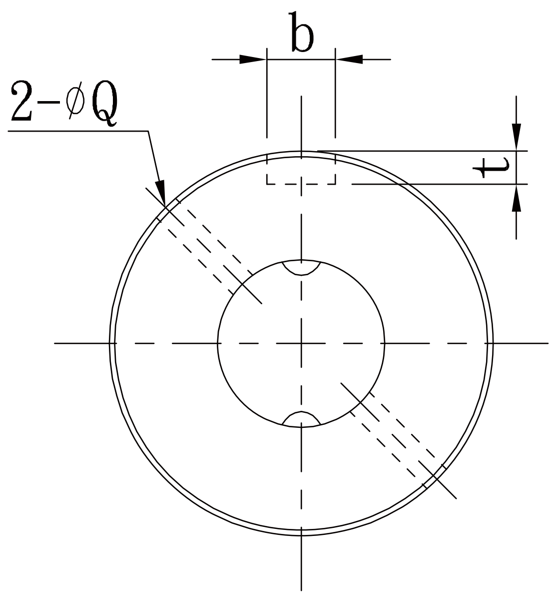
(Four Trains of Balls)

Model No	Spline-Nut Dimensions								Shaft Diameter	No. of Trains of Balls
	D	L	A	B	F	Oil Hole Q	W	Mounting Hole X x Y x Z	d h7	
SLF 6	14	25	30	6	7.5	1	22	3.4x6.5x4.5	6	2
SLF 8	16	27	32	8	7.5	1.5	24	3.4x6.5x4.5	8	2
SLF 10	21	33	42	9	10.5	1.5	32	4.5x8x4	10	2
SLF 13	24	36	44	9	11	1.5	33	4.5x8x4.5	13	2
SLF 16	31	50	51	10	18	2	40	4.5x8x6	16	2
SLF 20	35	56	58	10	18	2	45	5.5x9.5x5.4	20	2
SLF 25	42	71	65	13	26.5	3	52	5.5x9.5x8	25	4
SLF 30	47	80	75	13	30	3	60	6.6x11x8	30	4
SLF 40	64	100	100	18	36	4	82	9x14x12	40	4
SLF 50	80	125	124	20	46.5	4	102	11x17.5x12	50	4

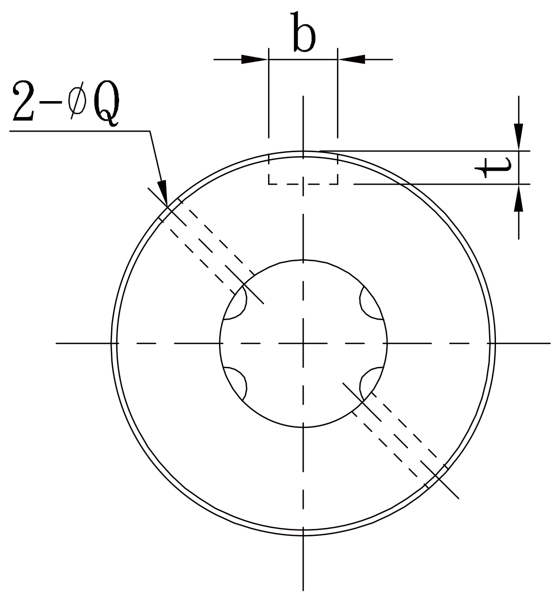


Basic Load Rating		Basic Torque Rating		Static Permissible Moment		Mass	
C	C_0	C_T	C_{0T}	M_{A1}	M_{A2}	Spline Nut	Spline Shaft
kgf	kgf	kgf・m	kgf・m	kgf・m	kgf・m	g	kg/m
137	225	0.46	0.76	0.39	3.48	36.7	0.22
137	225	0.60	0.99	0.39	3.82	47	0.39
285	397	1.62	2.25	0.95	8.53	100	0.60
396	540	2.89	3.94	1.50	12.46	117	1.03
545	849	4.77	7.43	3.71	26.09	226	1.56
724	1109	7.90	12.09	5.53	38.00	303	2.44
1003	1593	21.99	43.01	10.35	68.59	458	3.80
1160	1980	30.26	62.93	15.68	93.27	633	5.49
2972	4033	105.37	176.05	36.59	246.34	1430	9.69
4086	5615	179.89	304.35	51.58	428.72	2756	15.19

(Type: SLT)

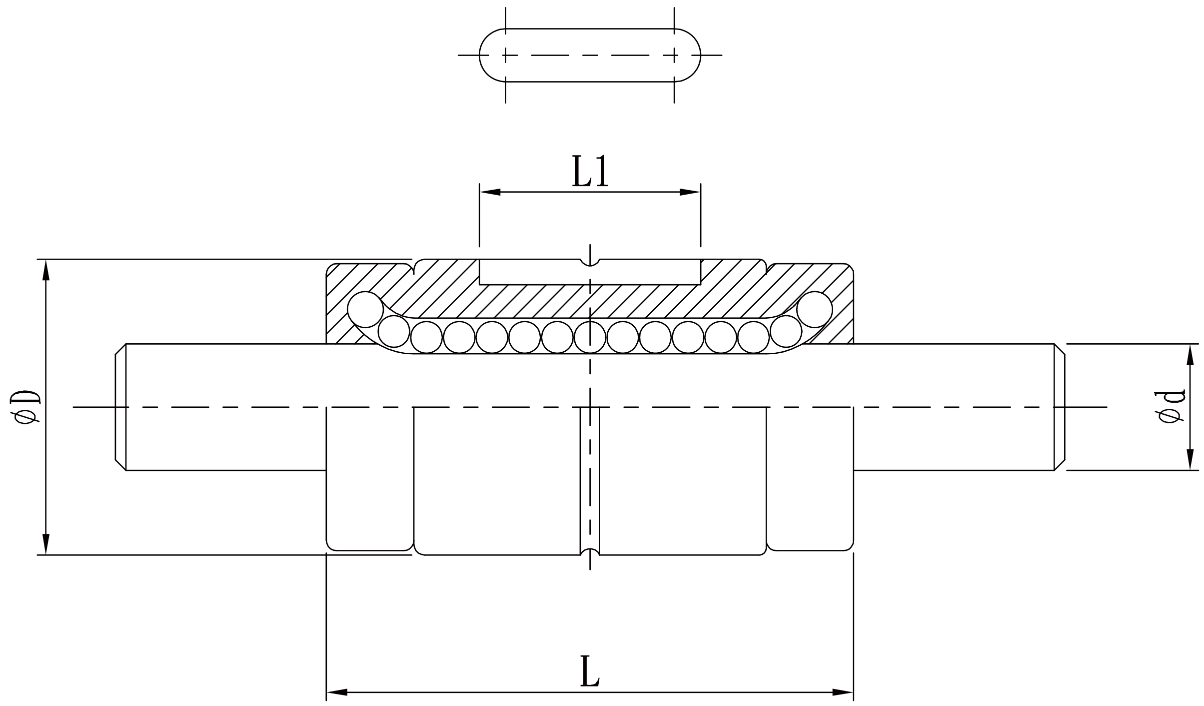


SLT 20 or Lower
(Two Trains of Balls)



SLT 25 or Higher
(Four Trains of Balls)

Model No	Spline-Nut Dimensions				Keyway Dimensions		Shaft Diameter	
	D	L	L1	Oil Hole Q	b H8	t +0.05 ~ 0	d h7	No. of Trains of Balls
SLT 6	14	25	10.5	1	2.5	1.2	6	2
SLT 8	16	27	10.5	1.5	2.5	1.2	8	2
SLT 10	21	33	13	1.5	3	1.5	10	2
SLT 13	24	36	15	1.5	3	1.5	13	2
SLT 16	31	50	17.5	2	3.5	2	16	2
SLT 20	35	56	29	2	4	2.5	20	2
SLT 25	42	71	36	3	4	2.5	25	4
SLT 30	47	80	42	3	4	2.5	30	4
SLT 40	64	100	52	4	6	3.5	40	4
SLT 50	80	125	58	4	8	4	50	4



Basic Load Rating		Basic Torque Rating		Static Permissible Moment		Mass	
C	C_0	C_T	C_{0T}	M_{A1}	M_{A2}	Spline Nut	Spline Shaft
kgf	kgf	kgf・m	kgf・m	kgf・m	kgf・m	g	kg/m
137	225	0.46	0.76	0.39	3.48	14	0.22
137	225	0.60	0.99	0.39	3.82	16	0.39
285	397	1.62	2.25	0.95	8.53	37	0.60
396	540	2.89	3.94	1.50	12.46	52	1.03
545	849	4.77	7.43	3.71	26.09	130	1.56
724	1109	7.90	12.09	5.53	38.00	188	2.44
1003	1593	21.99	43.01	10.35	68.59	285	3.80
1160	1960	30.26	62.93	15.68	93.27	395	5.49
2972	4033	105.37	176.05	36.59	264.34	843	9.69
4086	5615	179.89	304.35	51.58	428.72	1758	15.19

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