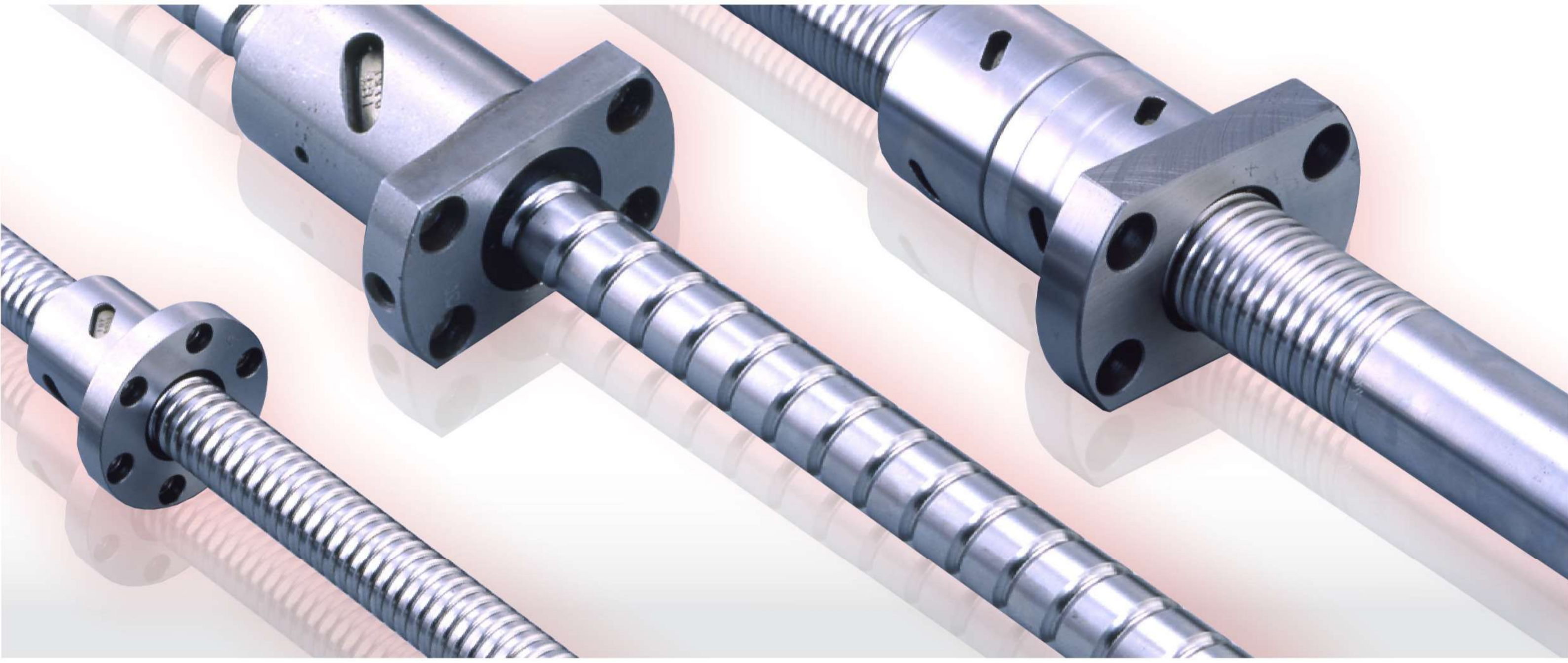


FUSO DE ESFERAS

1. About Ball Screw

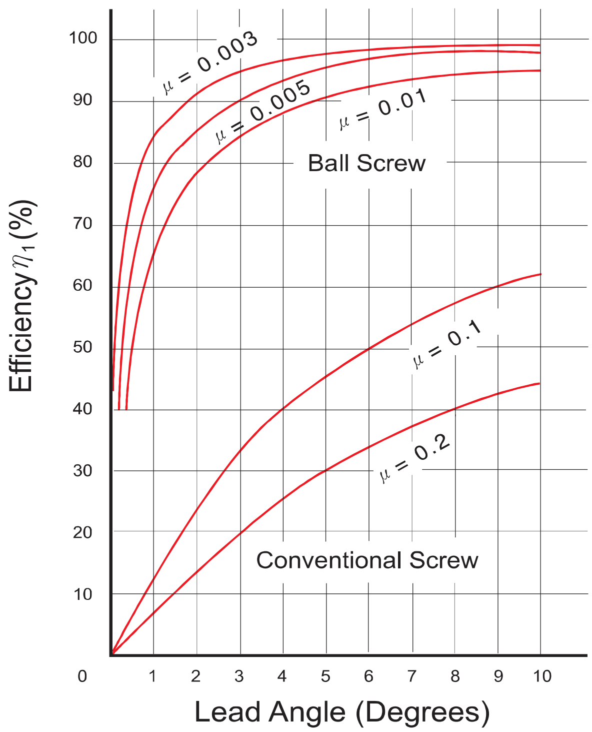
1-1 Features of Kalatec Automation Ball Screw

(1) High Reliability

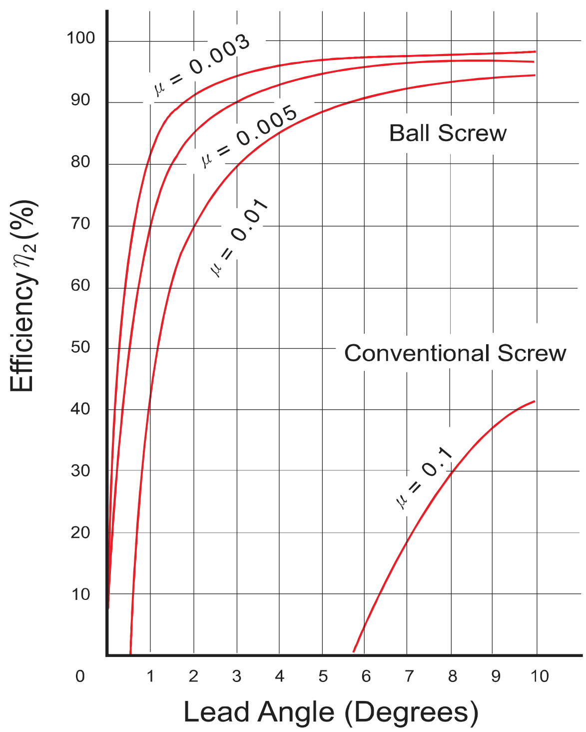
Kalatec Automation has very stringent quality control standards covering every production process. With proper lubrication and use, trouble-free operation for an estented period of time is possible.

(2) Smooth Operation

The high efficiency of ball screw is vastly superior to conventional screws as shown in Fig 1.1.1. The torque required is less than 30%. Linear motion can be easily changed from rotary motion.



Normal usage (to convert rotary motion to linear motion)



Special usage (to convert linear motion to rotary motion)

μ : friction coefficient

$$P = \frac{2\pi\eta_1 \times T}{\ell}$$

T = Torque kgf · cm

P = Force kgf

ℓ = Lead cm

η_1 = Efficiency

$$T = \frac{\ell \times \eta_2 \times P}{2\pi}$$

T = Torque kgf · cm

P = Force kgf

ℓ = Lead cm

η_2 = Efficiency

Fig 1.1.1 Mechanical Efficiency of Ball Screws

(3) High Rigidity and Preload

When axial play is minimized in conventional screw-nut assemblies, the actuating torque becomes excessive and the operation is not smooth. The axial play in Kalatec Automation precision ball screws may be reduced to zero by preloading and a light smooth operation is still possible. Therefore, both low torque and high rigidity can be obtained simultaneously. Kalatec Automation ball screws have gothic arch groove profiles (Fig1.1.2) which allow these conditions to be achieved.

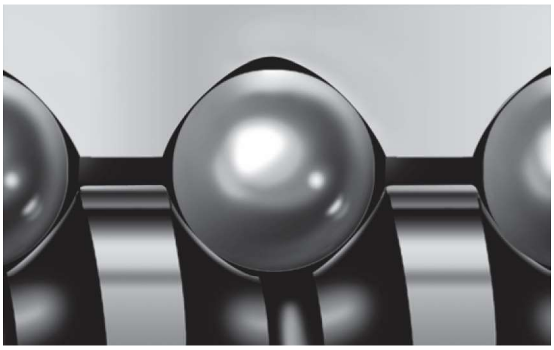


Fig 1.1.2 Groove Shape of Kalatec Automation Precision Ball Screw

(4) Circulation Method

Fig1.1.3 is ball return tube method.

Fig1.1.4 is ball defelector method.

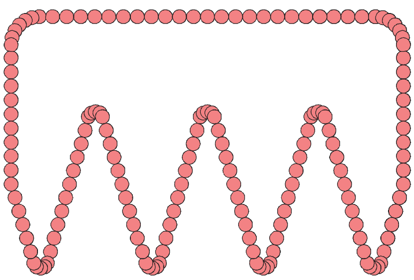


Fig 1.1.3 External Ball Circulation Nuts

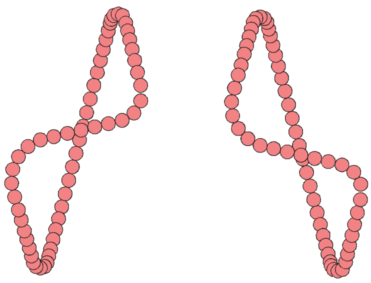


Fig 1.1.4 Internal Ball Circulation Nuts

(5) High Durability

Kalatec Automation Rigidly selected materials, intensive heat treating and processing techniques, backed by years of experience, have resulted in the most durable ball screws manufactured. (See Table1.1.1 & Fig1.1.5)

Table 1.1.1 Material and Heat Treatment

Item	Material	Hardness
Screw	SCM450 S55C	HRC 58°~64°
Nut	SCM415H SCM420H	HRC 58°~64°
Stell Ball	SUJ2	HRC 60° UP

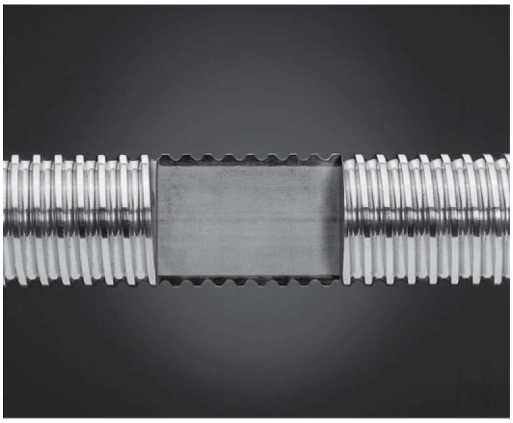
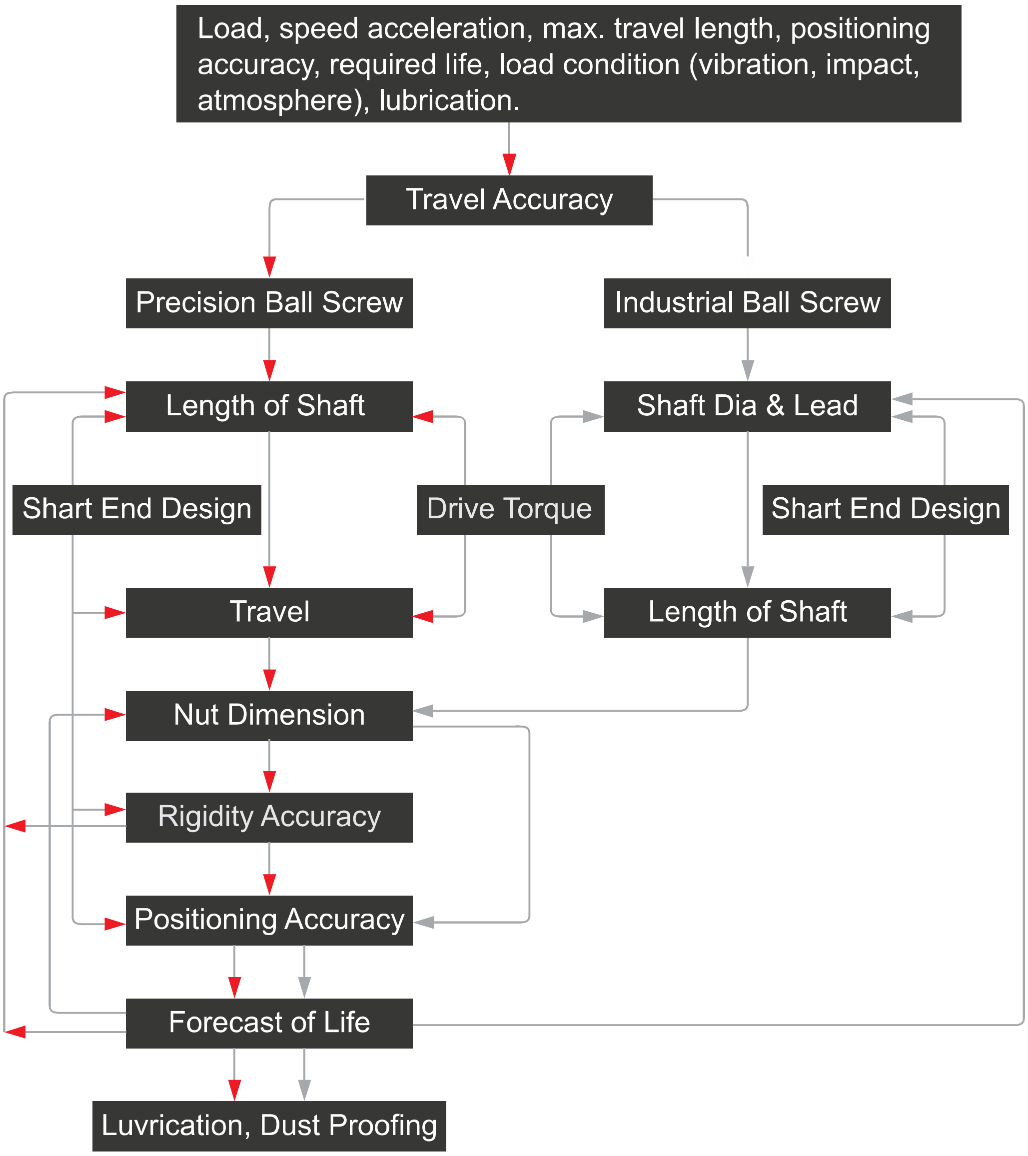


Fig 1.1.5 Heat Treatment

1-2 Ball Screw Selection Precedure



Accuracy (C04)

Screw Shart Design (C10)

Drive Torque (C16)

Nut Design (C17)

Rigidity (C20)

Positioning Accuracy (C23)

Life Design (C25)

Lubrication and safety design (C31)

1-3 Accuracy

1-3-1 Lead／Travel Accuracy

Lead accuracy of Kalatec Automation ball screws (grade C0~C5) is specified in 4 basic terms (E, e, e_{300}, $e_{2\pi}$). There are defined in Fig 1.3.1 Tolerance of deviation (± E) and variation (e) of accumulated reference travel are shown in Table 1.3.1~1.3.3.

Accumulated travel deviations for grade C7 and C10 are specified only by the allowable value per 300mm measured within any portion of the thread length. They are 0.05mm for C7 and 0.21mm for C10.

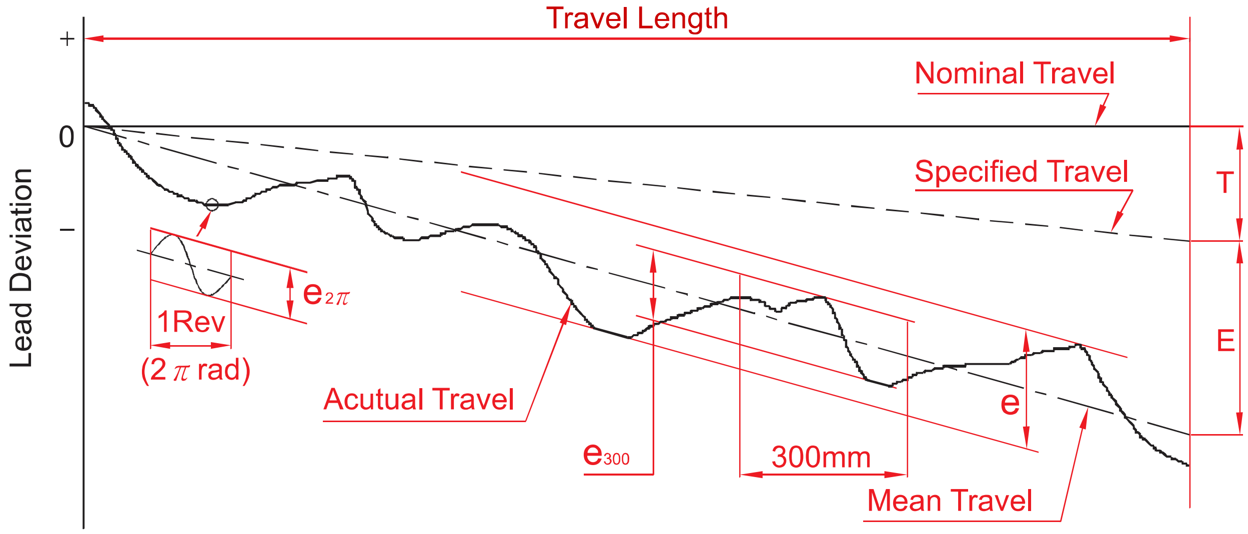


Fig 1.3.1 Diagram of Lead Accuracy

Table 1.3.1 Definition of terms for Lead Accuracy

Terms	Reference	Definition	Allowable
Travel Compensation	T	Travel compensation is the difference between specified and nominal travel with in the useful travel. A slightly smaller value compared to the nominal travel is often selected by the customer to compensate for an expected elongation caused by temperature rise or external load. Therefore " T " is usually a negative value. Note : if no compensation is needed, specified travel is the same as nominal travel.	
Actual Travel		Actual travel is the axial displacement of the nut relative to the screw shaft.	
Mean Travel		Mean travel is the linear best fit line of actual. This could be obtained by the least squares method. This line represents the tendency of actual travel.	
Mean Travel Deviation	E	Mean travel deviation is the difference beteen mean travel and specified travel within travel length.	Table 1.3.2
Travel Variations	e e_{300} $e_{2\pi}$	Travel variations is the band of 2 lines drawn parallel to the mean travel, on the plus and minus side. Maximum width of varation over the travel length. Actual width of variation for the length of 300mm taken anywhere within the travel length.Wobble error, actual width of variation for one revolution (2π radian)	Table 1.3.2 Table 1.3.3 Table 1.3.3

Table 1.3.2 Mean Travel Deviation (± E) and Travel Variation (e) (JIS B 1192)

Unit : μm

Grade			C0		C1		C2		C3		C5		C7	C10
Travel Length (mm)	Over	Incl.	±E	e	±E	e	±E	e	±E	e	±E	e	e	e
		100	3	3	3.5	5	5	7	8	8	18	18		
	100	200	3.5	3	4.5	5	7	7	10	8	20	18		
	200	315	4	3.5	6	5	8	7	12	8	23	18		
	315	400	5	3.5	7	5	9	7	13	10	25	20		
	400	500	6	4	8	5	10	7	15	10	27	20		
	500	630	6	4	9	6	11	8	16	12	30	23		
	630	800	7	5	10	7	13	9	18	13	35	25		
	800	1000	8	6	11	8	15	10	21	15	40	27		
	1000	1250	9	6	13	9	18	11	24	16	46	30		
	1250	1600	11	7	15	10	21	13	29	18	54	35	±50/300mm	±210/300mm
	1600	2000			18	11	25	15	35	21	65	40		
	2000	2500			22	13	30	18	41	24	77	46		
	2500	3150			26	15	36	21	50	29	93	54		
	3150	4000			30	18	44	25	60	35	115	65		
	4000	5000					52	30	72	41	140	77		
	5000	6300					65	36	90	50	170	93		
	6300	8000							110	60	210	115		
	8000	10000									260	140		
	10000	12500									320	170		

Table 1.3.3 Varation per 300mm (e_{300}) and Wobble Error ($e_{2\pi}$) (JIS B 1192)

Unit : μm

Grade	C0	C1	C2	C3	C5	C7	C10
e_{300}	3.5	5	7	8	18	50	210
$e_{2\pi}$	2.5	4	5	6	8		

1-3-2 Axial Play

Accuracy grade and axial play of Kalatec Automation's precision ball screw is shown in Table 1.3.4

Table 1.3.4 Combination of Accuracy Grade and Axial Play

Grade	P0	P1	P2	P3	P4
Axial Play	Yes	No	No	No	No
Preload	No	No	Light	Medium	Heavy

Excessive preload increase the friction torque and generates heat which reduce the life expectancy. However, insufficient preload reduces stiffness and increase the possibility of lost motion. Kalatec recommends that the preload force applied on CNC machine tolls should not bigger than 8% of the dynamic load; 5% for industrial automation X-Y table.

Table 1.3.5 The reference spring force of (P2)

Model No.	Spring Force (Kg) Single Nut	Spring Force(Kg) Double Nut
1605	0.1~0.3	0.3~0.6
2005	0.1~0.3	0.3~0.6
2505	0.2~0.5	0.3~0.6
3205	0.2~0.5	0.5~0.8
4005	0.2~0.5	0.5~0.8
2510	0.2~0.5	0.5~0.8
3210	0.3~0.6	0.5~0.8
4010	0.3~0.6	0.5~0.8
5010	0.3~0.6	0.8~1.2
6310	0.6~1.0	0.8~1.2
8010	0.6~1.0	0.8~1.2

Table 1.3.6 Axial Play (P0) Clearance in the Axial Direction of Rolled and Ground Ball Screw

Unit : mm

Nominal Diameter	Rolled Ball Screw Clearance in the Axial Direction (max.)	Ground Ball Screw Clearance in the Axial Direction (max.)
Ø04~Ø14 miniature ball screw	0.05	0.015
Ø15~Ø40 middle size of ball screw	0.08	0.025
Ø50~Ø100 big size of ball screw	0.12	0.05

1-3-3 Definition of Mounting Accuracy and Tolerance on Ball Screw

To use a ball screw properly dimensional accuracy and tolerances are most important. Kalatec will help you determine the tolerance factors as they are subject to change according to accuracy grade.

(1) Periphery run-out of the supporting part of the screw shaft to tha screw groove.

(2) Concentricity of a mounting portion of the shaft to the adjacent ground portion of the screw shaft.

(3) Perpendicularity of the shoulders to the adjacent ground portion of tha screw shaft.

(4) Perpendicularity of the nut flange to the axis of the screw shaft.

(5) Concentricity of the ba   nut diameter to the screw groove.

(6) Parallelism of the mounting surface of a ball nut to the screw groove.

(7) Total run-out of the screw shaft to the axis of the screw shaft.

All Kalatec ball screws are manufactured, inspected and guaranteed to be within specifications.

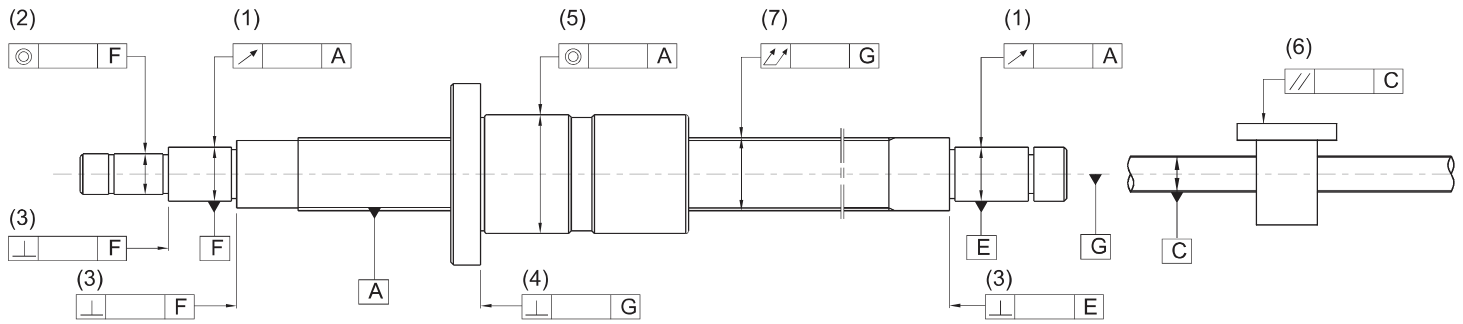


Fig 1.3.2 Mounting Accuracy and Tolerance

1-3-4 Preload Torque

Terms in relation to the preload torque generated during the rotation of the preload ball screws are shown in Fig 1.3.8.

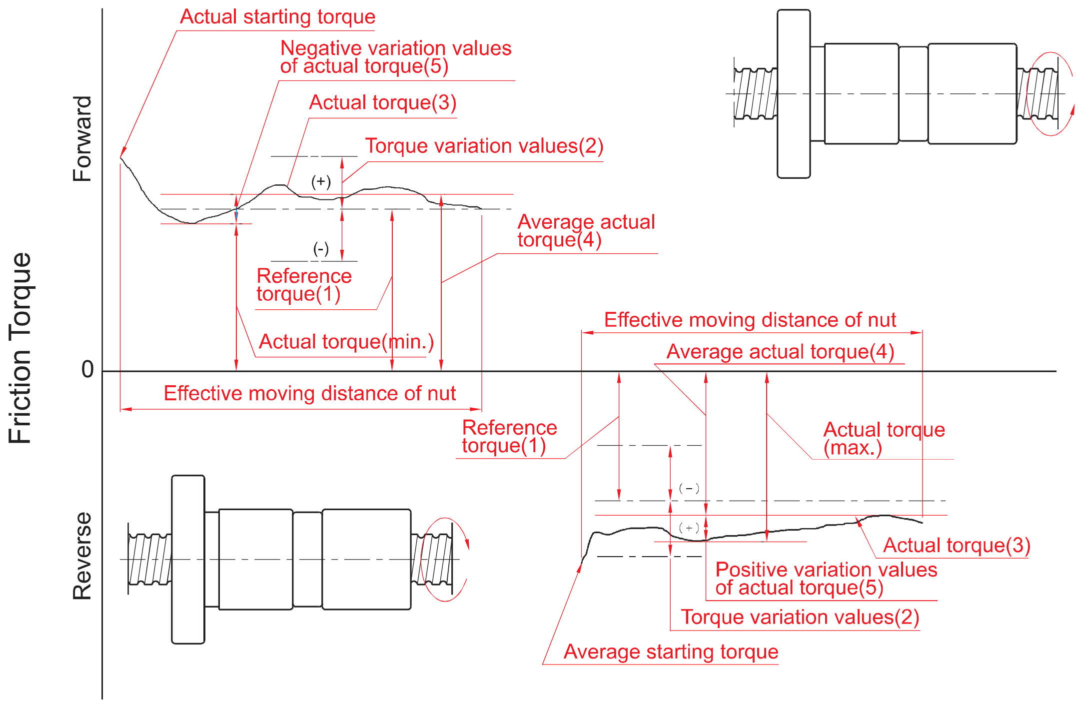


Fig 1.3.3 Descriptions of preload torque

Glossary

(1) Preload

The stress generated inside the screws when inserting a set of steel balls of one gage (approximately 2μ)larger into the nut or using them on the 2 nuts which exercise mutual displacements along the screws axis in order to eliminate the gaps of the screw or upgrade the rigidity of the screw.

(2) Preload dynamic torque

The dynamic torque required for continuously rotating the screws shaft or the nuts under unload condition after the special preload has been applied upon the ball screws.

(3) Reference

The targeted preload dynamic torque Fig 1.3.3-(1)

(4) Toque variation values

The variation values of the targeted preload torque variation rates are specilied generally based on JIS standards as indicated in Table.

(5) Torque variation rate

The rate of variation values in relation to the referance torque.

(6) Actual torque

The actually measured preload dynamic torque of the ball screws.

(7) Average actual torque

The arithmetic average of the maximal and minimal actual torque values measured when the nuts are exercieing reciprocating movements.

(8) Actual torque variation values

The maximal variation values measured within the effective length of the threads when the nuts are exercising reciprocating movements, the positive or negative values relative to the actual torque are adopted.

(9) Actual torque variation rate

The rate of actual torque variation values in relation of the average actual torque.

Table 1.3.7 Permissible ranges of toque variation rates

Reference torque kgf・cm		Effective threading length mm										
		Below 4000								4000~10000		
		Slenderness 1: below 40				Slenderness1:40~1:60				-		
		Grade				Grade				Grade		
Over	Incl	C0	C1	C2, C3	C5	C0	C1	C2, C3	C5	C1	C2, C3	C5
2	4	±35%	±40%	±45%	±55%	±45%	±45%	±55%	±65%	-	-	-
4	6	±25%	±30%	±35%	±45%	±38%	±38%	±45%	±50%	-	-	-
6	10	±20%	±25%	±30%	±35%	±30%	±30%	±35%	±40%	-	±40%	±45%
10	25	±15%	±20%	±25%	±30%	±25%	±25%	±30%	±35%	-	±35%	±40%
25	63	±10%	±15%	±20%	±25%	±20%	±20%	±25%	±30%	-	±30%	±35%
63	100	-	-	±15%	±20%	-	-	±20%	±25%	-	±25%	±30%

Remarks : 1. Slenderness is the value of dividing the screws shaft outside diameter with the screws shaft threading length.
2. For reference torque less than 2 kgf・cm, Kalatec specifications will apply.

Calculation of Reference Torque Tp

The formula for computing reference torque of the ball screws is given in following :

$$T_P = 0.05\,(\tan\beta)^{-0.5} \cdot \frac{Fao \cdot \ell}{2\pi}$$

Where, Fao = Preload (kgf)

β = Lead angle

ℓ = Lead (cm)

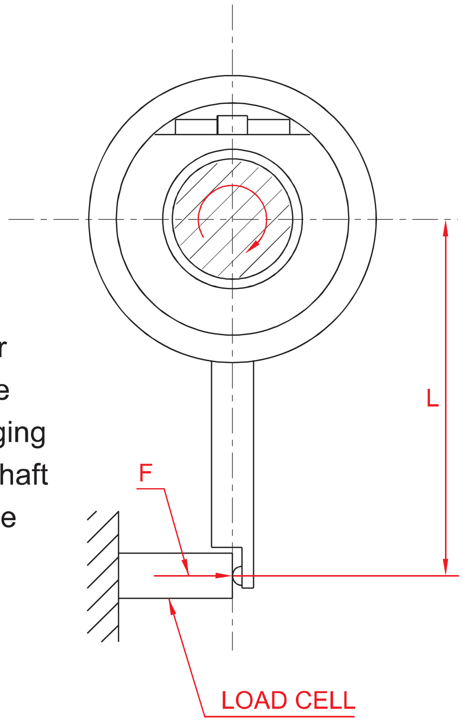


Fig 1.3.4 Preload dynamic torque measuring method

Measurement Conditions

The preload dynamic torque T_p is determined first by adopting the following measurement conditions together with the method illustrated in Fig 1.3.4 for measuring the force (F) needed to rotate the screws shaft without bringing the nuts to rotate along with the shaft after the screws shaft has started rotating, then multiplying the measured value of (F) with the arm of force L, the product is T_p.

$T_p = F \cdot L$

Measure conditions

(1) Measurment is executed under the condition of not attaching with scraper.

(2) The rotating speed during measurement maintains at 100 rpm.

(3) According to JSK2001(industrial lubrication oil viscosity) be in compliance standard), the lubrication oil used should be in complience with IS0 VG68.

1-4 Screw Shaft Design

1-4-1 Mounting Methods

Both the critical speed and column bucking load depend upon the method of mounting and the unsupported length of the shaft, the most common mounting methods for ball screws are shown in Fig 1.4.1~1.4.8.

(Mounting Screw and Nut)

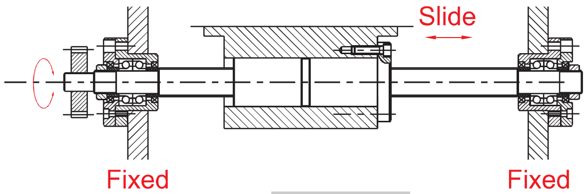


Fig 1.4.1

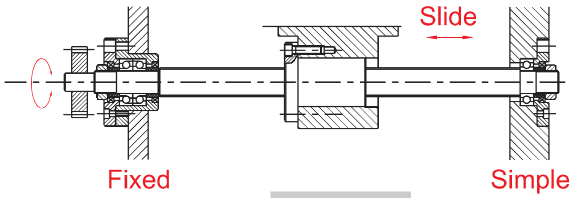


Fig 1.4.5

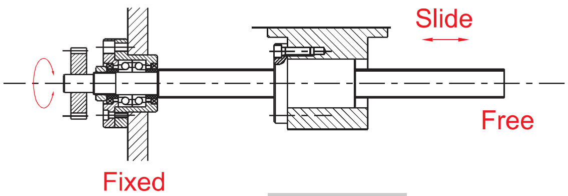


Fig 1.4.2

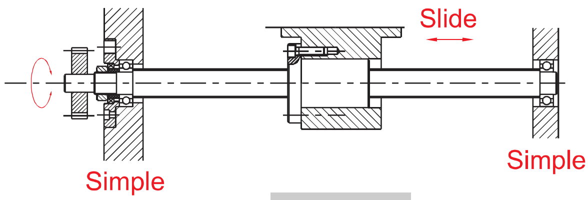


Fig 1.4.6

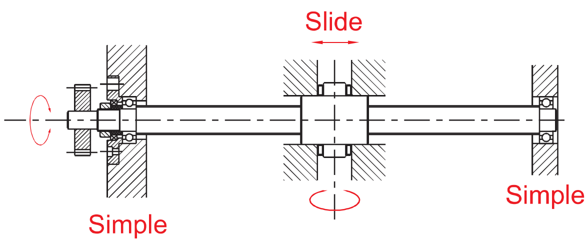


Fig 1.4.3

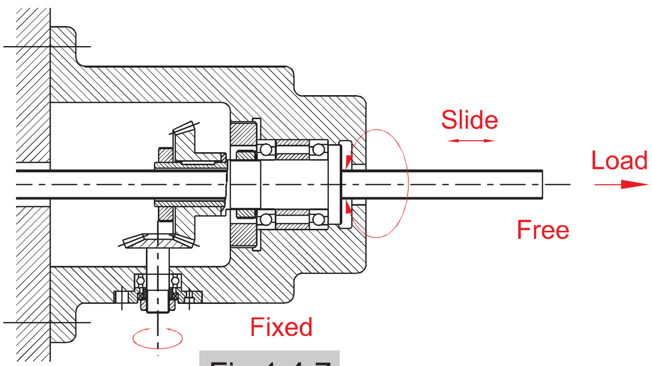


Fig 1.4.7

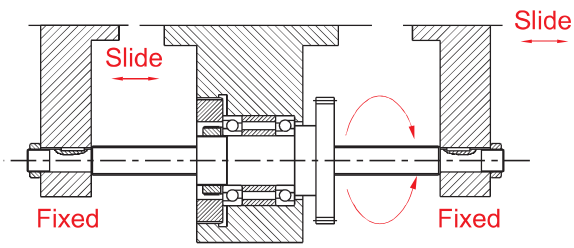


Fig 1.4.4

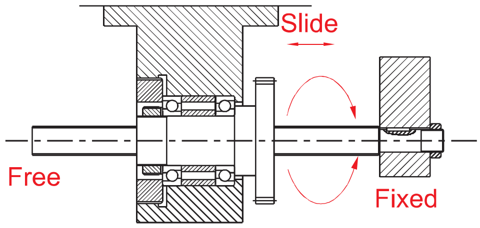


Fig 1.4.8

(Mounting Methods)

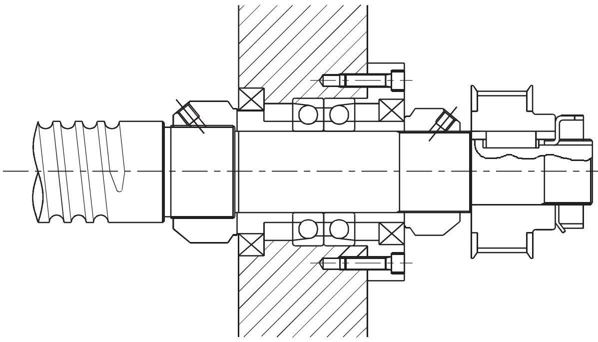


Fig 1.4.9

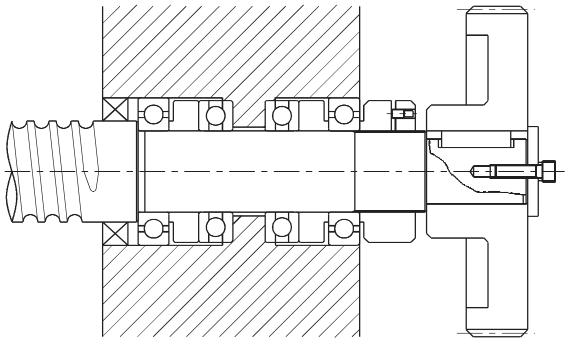


Fig 1.4.11

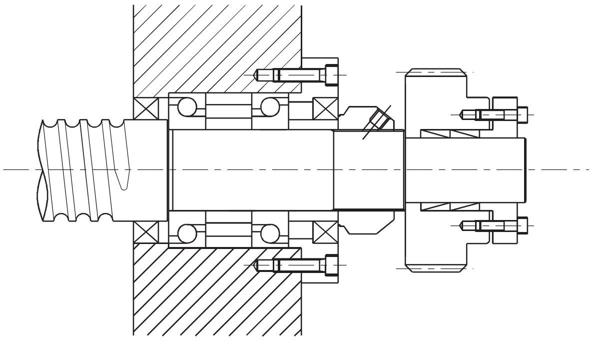


Fig 1.4.10

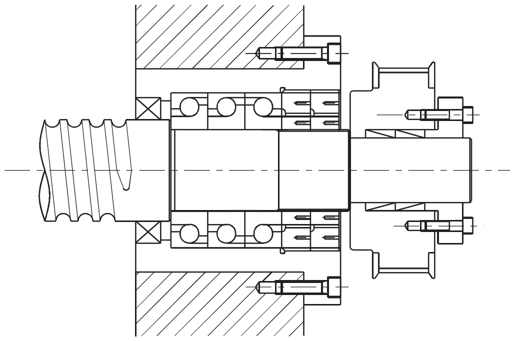


Fig 1.4.12

(Most Common Mounting Methods for Ball Screws)

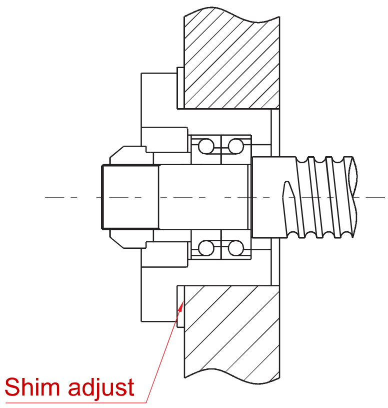


Fig 1.4.13

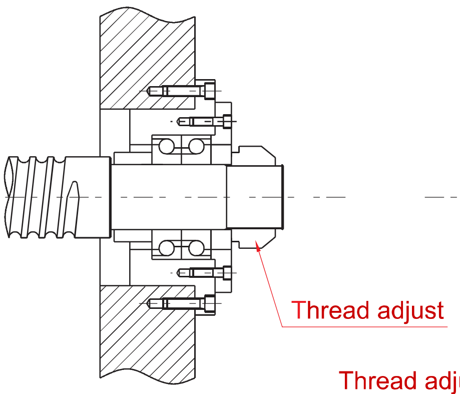


Fig 1.4.14

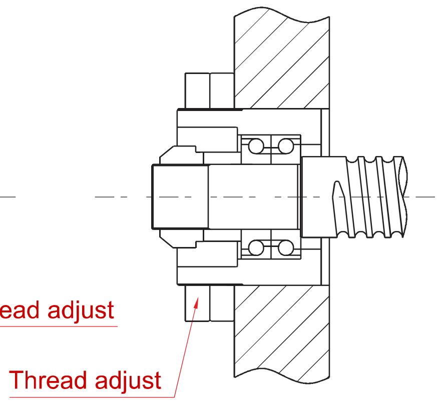


Fig 1.4.15

1-4-2 Allowable Axial Load

(1) Buckling Load

The safety of the screw shaft against buckling needs to be checked when the shaft is expected to receive buckling loads.

Fig 1.4.16 shows a diagram which summarizes the allowable compressive load for buckling for each nominal outside diameter of screw shaft. (Calculate with the equation shown right when the nominal outside diameter of the screw shaft exceeds 125mm.)

Select the graduation of allowable axial load according to the method of ball screw support.

$$P = \alpha \cdot \frac{I \cdot N \cdot \pi^2 \cdot E}{L^2} = m \frac{dr^4}{L^2} \cdot 10^3$$

Where

α = Safty Factor (α = 0.5)

E ：Vertical elastic modules

($E = 2.1 \cdot 10^4$ kgf／mm^2)

I ：Min. secondary moment of screw shaft sectional area

$I = \frac{\pi}{64} dr^4$ (mm^4)

dr ：Screw shaft root diameter (mm)

L ：Mounting distance (mm)

m・N：Coefficient determined from mounting method of ball screw

Simple-Simple	m = 5.1	(N = 1)
Fixed-Simple	m = 10.2	(N = 2)
Fixed-Fixed	m = 20.3	(N = 4)
Fixed-Free	m = 1.3	(N = 1／4)

(2) Allowable Tensile／Buckling Load

Check the allowable tensile／buckling load (the formula shown below) and allowable load of the ball groove regardless of the mounting method when the mounting distance is short.

$P = \sigma A = 11.8\, dr^2$ (kgf)

Where,

P : Buckling load (kgf)

σ : Allowable tensile compressive stress (kgf／mm^2)

A : Sectional area of screw shaft root bottom diameter (mm^2)

dr : Screw shaft root diameter (mm)

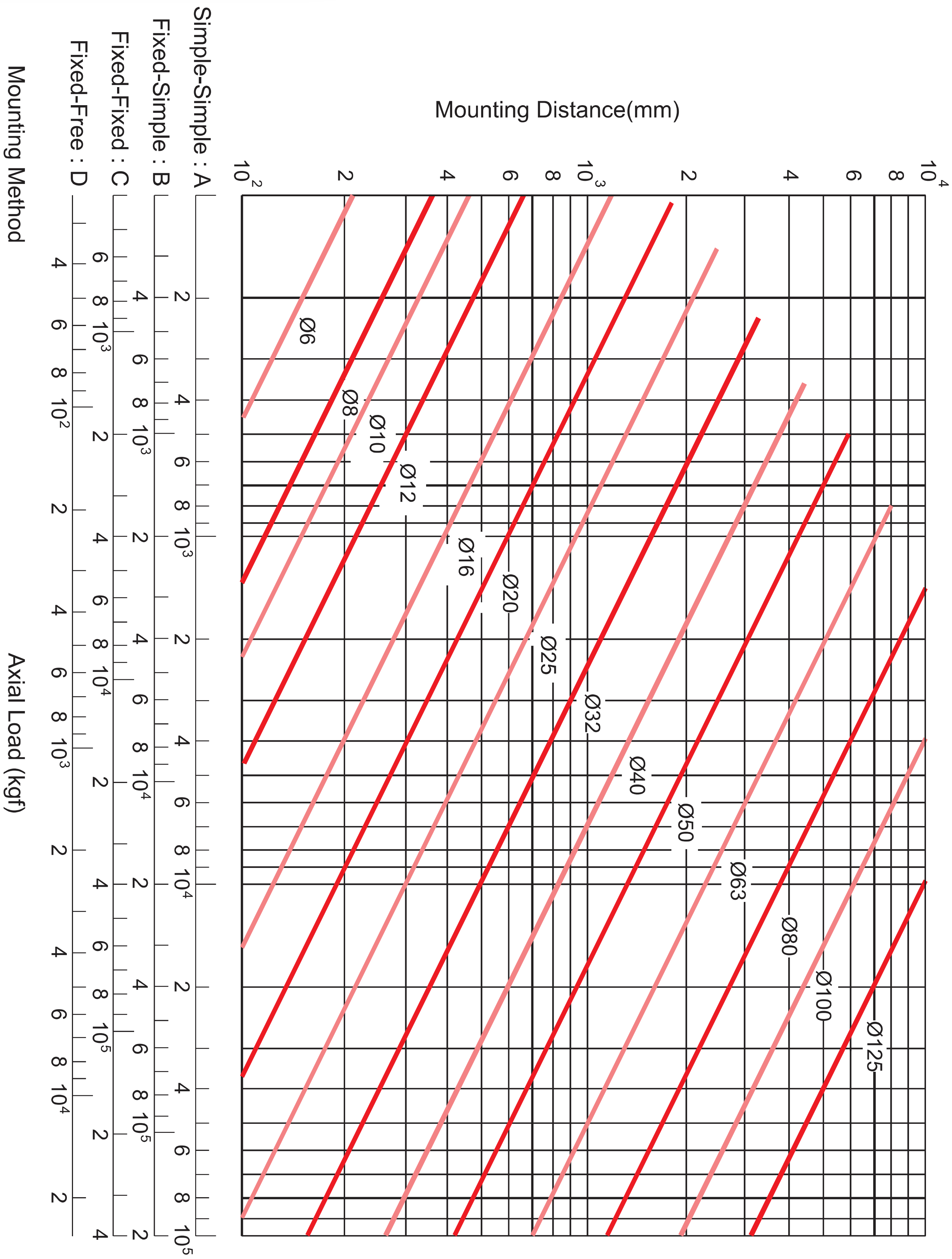


Fig 1.4.16 Buckling Load vs. Nominal Diameter and Length

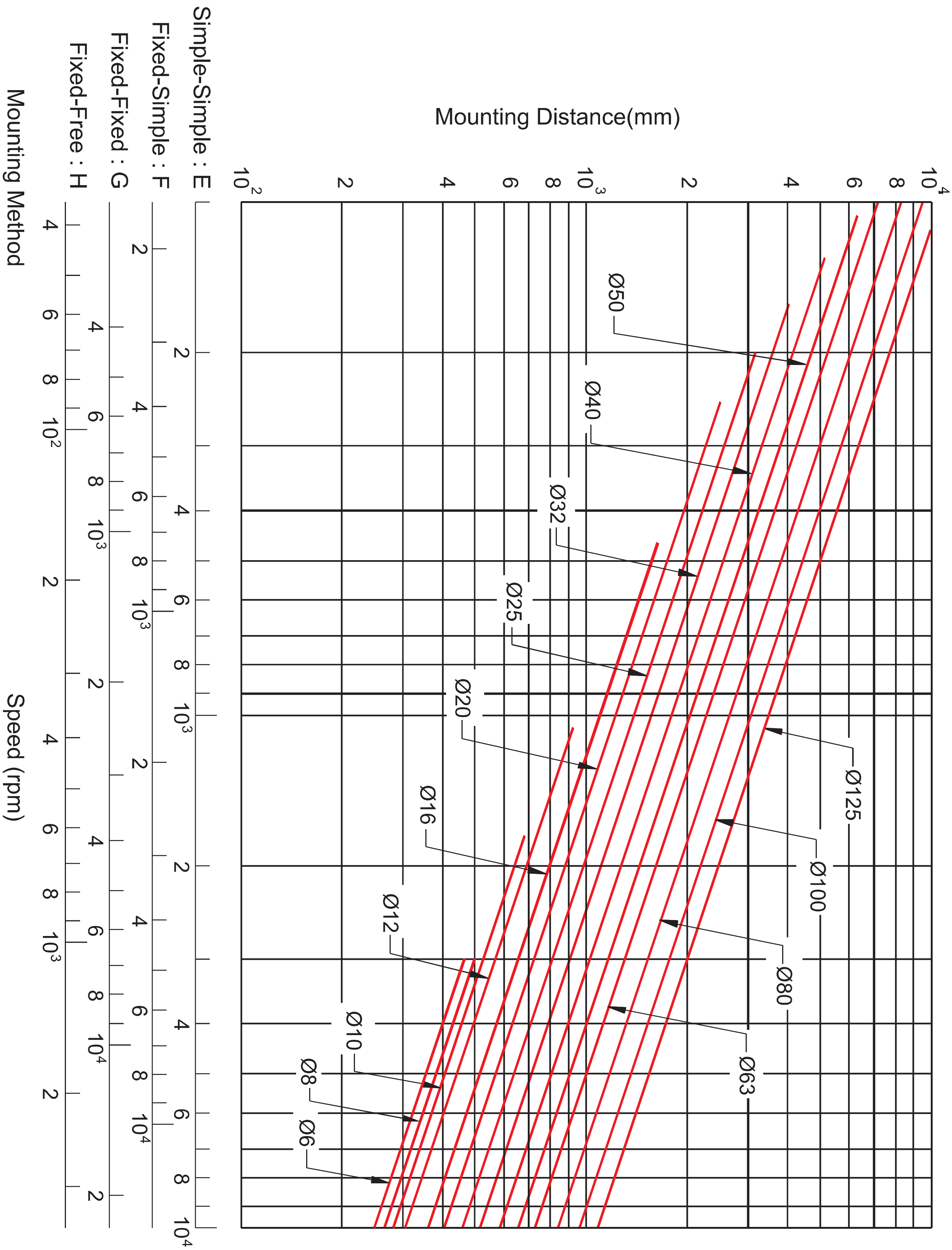


Fig 1.4.17 Critical Speed vs. Nominal Diameter

1-4-3 Critical Speed

(1) Dangerous speed

It is necessary to check if the ball screw rotation speed is resonant with the natural frequency of the screw shaft. Kalatec Automation has determined 80% or less of this critical speed as an allowable rotation speed. Fig 1.4.17 shows a diagram which summarizes the allowable rotation speed for shaft nominal diameters up to outside diameter of the screw shaft exceeds 125mm.) Select the graduation of allowable rotation speed according to the method of supporting the ball screw. Where the working rotation speed presents a problem in terms of critical speed, it would be best to provide an intermediate support to increase the natural frequency of the screw shaft.

(2) dm・n value

The allowable rotation speed is regulated also by the dm・n value (dm : diameter of central circle of steel ball, n : Revolution speed, rpm) which expresses the peripheral speed.

Generally,

For precision

(accuracy grade C7 to C0)

dm・n ≦ 70,000

For general industry (C10)

dm・n ≦ 50,000

Product exceeding the above limits can be produced, contact Kalatec Automation

※Particular consideration is necessary for manufacturing with the screw length／shaft dia. Ratio is $\varepsilon > 70$, In such an event, contact Kalatec Automation

$$n = \alpha \cdot \frac{60\lambda^2}{2\pi L^2}\sqrt{\frac{EIg}{\gamma A}} = f\frac{dr}{L^2}\cdot 10^7 \text{ (rpm)}$$

Where

α : Safty factor (α = 0.8)

E : Verticle elastic modules (E = $2.1 \cdot 10^4$ kgf／mm^2)

I : Min. secondary moment of screw shaft sectional area

$I = \frac{\pi}{64} dr^4 (mm^4)$

dr : Screw shaft root diameter (mm)

g : Acceleration of gravity (g = $9.8 \cdot 10^3$ mm／s^2)

γ : Density (γ = $7.8 \cdot 10^{-6}$ kgf／mm^3)

A : Screw shaft sectional area (A = πdr^2／4 mm^2)

L : Mounting distance (mm)

f, λ : Coefficient determined from the ball screw mountung metnod

Simple-Simple f = 9.7 ($\lambda = \pi$)

Fixed-Simple f = 15.1 (λ = 3.927)

Fixed-Fixed f = 21.9 (λ = 4.730)

Fixed-Free f = 3.4 (λ = 1.875)

1-5 Driving Torque

1-5-1 Driving torque Ts of the transmission shaft

$T_S = T_P + T_D + T_F$ (in fixed speed)

$T_S = T_G + T_P + T_D + T_F$ (when accelerating)

T_G : Acceleration torque (1)

T_P : Load torque (2)

T_D : Preload torque (3)

T_F : Friction torque (4)

(1) Acceleration T_G

$T_G = J\alpha$ (kgf · cm)

$\alpha = \dfrac{2\pi n}{60\triangle t}$ (rad／s^2)

J : Moment of inertia (kgf · cm · s^2)

α : Angular acceleration (rad／s^2)

n : Revolutions (min^{-1})

$\triangle t$: Starting time (sec)

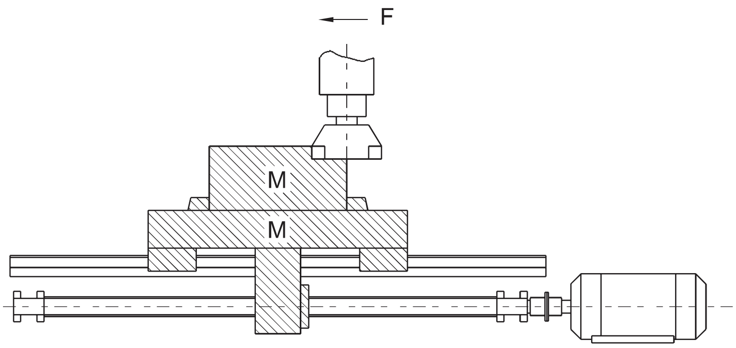


Fig 1.5.1 Moment of inertia of load

【For reference】Moment ot inertia of load (see Table 1.5.1)

$J = J_{BS} + J_{CU} + J_W + J_M$

J_{BS} : Moment of inertia Ball screws shaft

J_{CU} : Moment of inertia Coupler

J_W : Moment of inertia Linear motion part

J_M : Moment of inertia Roller shaft part of motor shaft

(2) Load torque T_P

$T_P = \dfrac{P \cdot \ell}{2\pi\eta_1}$ (kgf · cm)

$P = F + \mu Mg$

P : Axial load (kgf)

ℓ : Load (cm)

η_1 : Positive efficient

└→ The efficient when rotating motion is altered to linear motion

F : Cutting force (kgf)

μ : Friction

M : Mass of moving object (kg)

g : Acceleration of gravity (9.8 m／s^2)

$T_P = \dfrac{P \cdot \ell \cdot \eta_2}{2\pi}$ (kgf · cm)

η_2 : Reverse efficiency

└→ The efficiency when linear motion returns to rotating motion

(3) Preload torque T_D

$T_D = \dfrac{K \cdot P_{PL} \cdot \ell}{\sqrt{\tan\alpha} \cdot 2\pi}$ (kgf · cm)

K : Internal coefficient (0.05 is usually adopted)

P_{PL} : Preload (kgf)

ℓ : Lead (cm)

α : Lead angle

(4) Fricition torque T_F

$T_F = T_B + T_O + T_J$ (kgf · cm)

T_B : Friction torque of bracing shaft

T_O : Friction torque of free shart

T_J : Friction torque motor shaft

The friction torque of the bracing shaft would be affected by the lubrication oil. Or special attention has to be paid to unexpected excessive friction torque which may be generated when oil seal is overly tight, or may result in temperrature rise.

Table1.5.1 Conversion formula for moment of inertia of load

Formula / Moment of inertia converted from motor shaft	J
Cylinder load	$\frac{\pi \rho L D^4}{32}$
Linearly moving object	$\frac{M}{4}\left(\frac{V\ell}{\pi \cdot N_M}\right)^2 = \frac{M}{4}\left(\frac{P}{\pi}\right)^2$
Unit	$kg \cdot m^2$
Moment of inertia during deceleration	$J_M = \left(\frac{J\ell}{N_M}\right)^2 \cdot J\ell$

ρ : Density (kg/m^3) $\rho = 7.8 \cdot 10^3$

L : Cylinder length (m)

D : Cylinder (m)

M : Mass of the linear motion part (kg)

$V\ell$: Velocity of the linear moving object (m／min)

N_M : Motor shaft revolutions (min^{-1})

P : The moving magnitude of the linearly moving object per every rotation of the motor (m)

$N\ell$: Rotations in longitudinal moving direction (min^{-1})

$J\ell$: Moment of inertia in load direction

J_M : Moment of inertia in motor direction

1-6 Nut Design

1-6-1 Selection of Nut

(1) Series

When making selection of series, please take into consideration of demanded accuracy, intended delivery time, dimensions (the outside diameter of the screw, ratio of lead／the outside diameter of the screw,) preload load, etc.

(2) Circulation type

Selection of circulation type : Please focus on the economy of space for the nut installation portion.

(3) Number of loop circuits

Performance and life of service should be considered when selecting number of loop circuits.

(4) Shape of flanges (FLANGE)

Please make selection based on the available space for the installation of nuts.

(5) Oil hole

Oil holes are provided for the precision ball screws, please use them during machine assembling and regular furnishing.

Table1.6.1 Circulation type

Circulation type	Model		Characteristic
	Single Nut	Double Nuts	
Internal circulation type	BSH		●With nuts of finely crafted outside diameter (occupying small space) ●Applicable to those with smaller ead / the outside diameter of the screw
External circulation type	BSH		●Economy ●Suitable for mass production ●Applicable to those with larger lead / the outside
End-caps circulation type	SFY	DFS	●Suitable for high speed positioning

1-6-2 Nut Types

U, I, M - Type Nut

In this type, the steel balls move along the grooves of the internal circulator, diagonally pass over the tooth tops of the scraws,than return to the origin point. It generally posse-sses one roll of steel balls and one single pass circulation. (see Fig 1.6.1) It is generally provided with several rolls of steel balls and a single pass circulation tube, both round type and projecting tube type of profile may be adopted.

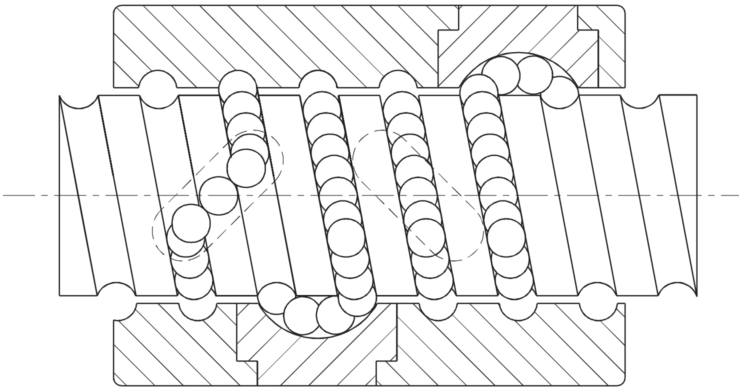


Fig 1.6.1 U, I, M - Type Nut

K - Type Nut

It applies the similar circulation as that of I-type, but circulation takes place in key slots of identical angle for different circulation. (see Fig 1.6.2)

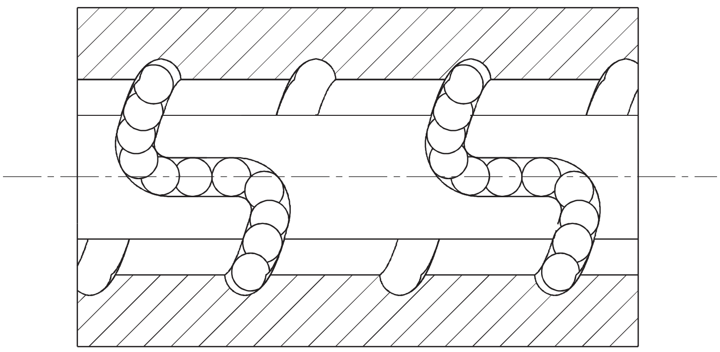


Fig 1.6.2 K - Type Nut

1-7 Rigidity

Excessively weak rigidity of the screw'speripheral structure is one of the primary causes that result in lost motion. Therefore, in order to achieve excellent positioning accuracy for the precison machines such as NC working machines, etc., axial rigidity balance as well as torsional rigidity for the parts at various portions of the transmission screw have to be taken into consideration at time of designing.

Static Rigidity K

The axial elastic deformation and rigidity of the transmission screw system can be determined form the formula below.

$$K = \frac{P}{e} \text{ (kgf/mm)}$$

P：Axial load (kgf) borne by the transmission screw system

e：Axial flexural displacement (mm)

$$\frac{1}{K} = \frac{1}{K_S} + \frac{1}{K_N} + \frac{1}{K_B} + \frac{1}{K_H} \text{ (mm/kgf)}$$

K_S：Axial rigidity of screw shaft (1)

K_N：Axial rigidity of nut (2)

K_B：Axial rigidity of support shaft (3)

K_H：Axial rigidity of installation (4)

(1) Axial rigidity Ks and displacement δs

$$K_s = \frac{P}{\delta s} \text{ (kgf/mm)}$$

P：Axial load (kgf)

For places of Fixed - Fixed installation

$$\delta_{SF} = \frac{PL}{4AE} \text{ (mm)}$$

For places other than Fixed - Fixed installation

$$\delta_{SS} = \frac{PL_0}{AE} \text{ (mm)}$$

$\delta_{SS} = 4\,\delta_{SF}$

δ_{SF}：Directional displacement at places of fixed-fixed

δ_{SS}：Directional displacement at places other than fixed-fixed installation

A：Cross-sectional area of the screw shaft tooth root diameter (mm^2)

E：Longitudinal elastic modulus ($2.1 \cdot 10^4$ kgf/mm^2)

L：Distance between installations (mm)

L_0：Distance between load applying points (mm)

V - Type Nut

The recycle way of V - type is similar with T - type. Besides maintaining the advantages of T - type, the design of circulation of the steel ball is also along the direction of tangent of helix and can decrease the sound from the hitting between steel ball and the direction of tangent of helix and increase the smooth of recyle. V - type nut is suitable for the high-speed and heavy-load situations specially. (see Fig 1.6.3)

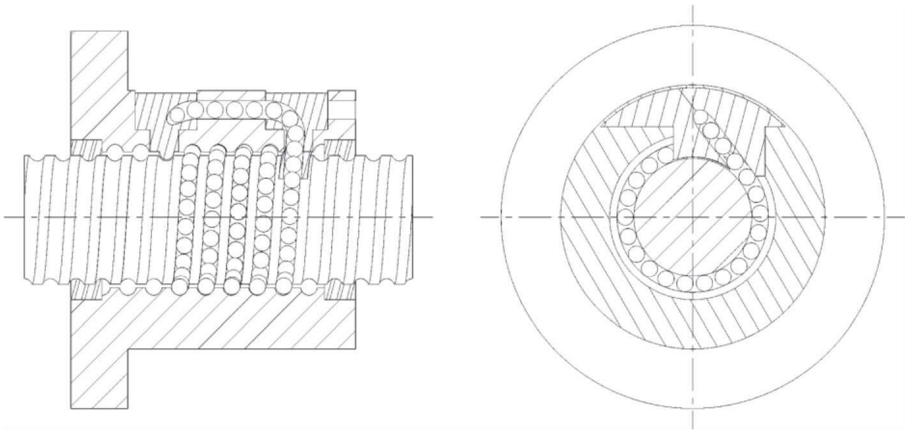


Fig 1.6.3 V - Type Nut

Y, H - Type Nut

Type Y ball nut is dimensionally interchangeable with type E ball nut and type H ball nut shares the dimension with Type S ball nut. Both of the above ball nuts adopt the same design in circulation system. Moreover, type Y and H ball nut is designed to strengthen the performance by introducing the thin-flex material for better performance in wiping ability and higher rigidity in circulation with reinforced circulation parts. (see Fig 1.6.4)

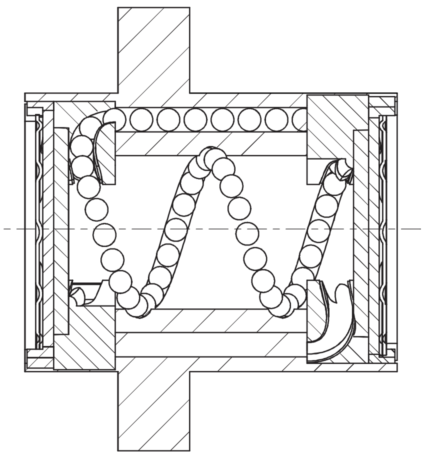


Fig 1.6.4 Y, H - type nut

(2) Axial rigidity K_N and displacement δ_N

$$K_N = \frac{P}{\delta_S}\ (\text{kgf/mm})$$

(a) In case of single nut

$$\delta_{NS} = \frac{K}{\sin\beta}\left(\frac{Q^2}{d}\right)^{\frac{1}{3}} \cdot \frac{1}{\zeta}\ (\text{mm})$$

$$Q = \frac{P}{n \cdot \sin\beta}\ (\text{kgf})$$

$$n = \frac{D_0\,\pi\,m}{d}\ (\text{each})$$

Q : Load of one steel ball (kgf)

n : Number of steel ball

k : Constant determined based on material, shape, dimensions

$k \fallingdotseq 5.7 \cdot 10^{-4}$

β : Angle of contact (45°)

P : Axial load (kgf)

d : Steel ball diameter (mm)

ζ : Accuracy, internal structure coefficient

m : Effective number of balls

D_0 : Steel ball center diameter (mm)

$$D_0 = \frac{\ell}{\tan\alpha \cdot \pi}$$

ℓ : Lead (mm)

α : Lead angle

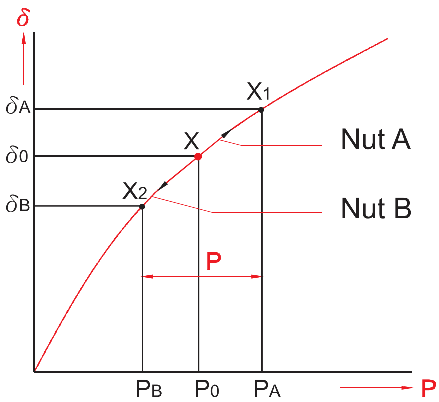


Fig 1.7.2

(b) In case of double nuts

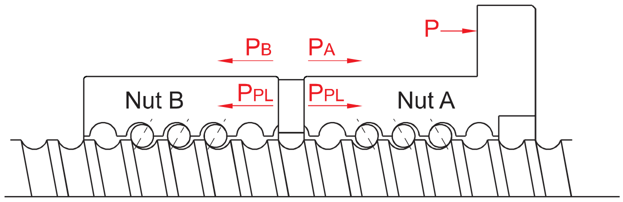


Fig 1.7.1 Preloaded for the double nuts

When an axial load P of approximately three times of preload load P_{PL} is exerted, for the purpose of eliminating the preload P_{PL} on nut B, please set the preload load P_{PL} at no more than 1/3 of the maximal preload. (0.25Ca should be taken as the standard maximal preload load) With respect to the displacement malue, it should be of 1/2 of the single nut displacement when axial load is three times of the preload.

$$K_N = \frac{P}{\delta_{NW}} = \frac{3P_{PL}}{\delta_{NS/2}} = \frac{6P_{PL}}{\delta_{NS}}\ (\text{kgf/mm})$$

δ_{NS} : Displacement of single nut(mm)

δ_{NW} : Displacement of doulbe nuts(mm)

(Explancement of the rigidity of double nuts)

As show in Fig 1.7.1 and 1.7.2, when a preload P_{PL} is applied on the 2 nuts A, B, both nuts A, B would produce flexural deformations that will reach point X. If an external force P is exerted from here, nut A would move from point X to point X_1, while nut B would move from X to X_2.

Then, based on the computing formula for displacement δ_{NS} of the single nut, we can obtain :

$\delta_0 = aP_{PL}^{\frac{2}{3}}$

while displacements of nuts A, B are $\delta_A = aP_{PL}^{\frac{2}{3}}$
since displacements of nuts A, B generated due to exertion of external force P are equal, therefore

$\delta_A - \delta_0 = \delta_0 - \delta_B$

Or if P is the only external force P applied on nuts A, B, if P_A increases.

$P_A - P_B = P$

$\delta_B = 0$

For preventing the external force applied on nut B being abosorbed by nut A thus decreaseing, so when $\delta_B = 0$

$aP_A^{\frac{2}{3}} - aP_{PL}^{\frac{2}{3}} = aP_{PL}^{\frac{2}{3}}$

$P_A^{\frac{2}{3}} = 2P_{PL}^{\frac{2}{3}}$

$P_A = \sqrt{8}\,P_{PL} \fallingdotseq 3P_{PL}$

or based on $\delta_A - \delta_0 = \delta_0$

$\delta_0 = \dfrac{\delta_A}{2}$

thus it can also be judged from Fig 1.7.3 that, with 1／2 displacement, the rigidity is two times as high.

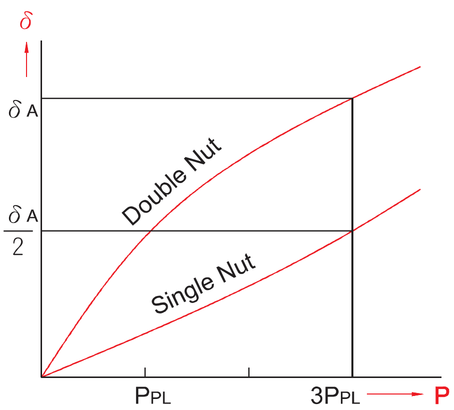


Fig 1.7.3

(3) Axial rigidity K_B and displacement δ_B of support shaft

$$K_B = \frac{P}{\delta_B} \text{ (kgf／mm)}$$

The rigidity of the assemble diagonal thrust bearind that is used as the support bearing for the ball screw and is widely unilized in the field of precision machines can be found from the following formula.

$$\delta_B = \frac{2}{\sin\beta}\left(\frac{Q^2}{d}\right)^{\frac{1}{3}}$$

$$Q = \frac{P}{n \cdot \sin\beta} \text{ (kgf)}$$

Q：Load of one steel ball (kgf)
n：Number of steel balls
β：Angle of contact (45°)
P：Axial load (kgf)
d：Steel ball diameter (mm)
ℓa：Effective stroke

(4) Axial rigidity K_H and displacement of δ_H portions of nuts and bearings. In early stage of machine development, special attentions should be paid to the require-ment of high rigidity for the installation portion.

$$K_H = \frac{P}{\delta_H} \text{ (kgf／mm)}$$

1-8 Positioning Accuracy

Among the factors that cause feed accuracy errors, lead stroke accouracy and feed system rigidity are the key points for review, while other factors such as heat deformation due to temperature rise as well as assenbly accuracy for the guiding surface, etc. should also be into consideration.

1-8-1 Accuracy Selection

Table 1.8.1 shows the recommended application ranges for various ball screws accuracy classes based on different.

Table 1.8.1 Examples of ball screws accuracy classes for different uses

Application			Accuracy Grade						
			C0	C1	C2	C3	C5	C7	C10
NC Machine Tools	Lathe	X	○	○	○	○	○	○	
		Y				○	○	○	
	Milling Machine Boring Machine	XY		○	○	○	○	○	
		Z			○	○	○	○	
	Machine Center	XY		○	○	○	○		
		Z			○	○	○		
	Jig Borer	Y	○	○					
		Z	○	○					
	Drilling Machine	XY				○	○	○	
		Z					○	○	
	Grinding Machine	X	○	○	○	○	○	○	
		Z		○	○	○	○	○	
	Electro-discharge Machine (EDM)	XY		○	○	○	○	○	
		(Z)			○	○	○	○	
	Wire Cut (EDM)	Y		○	○	○			
		UV		○	○	○	○	○	
	Punching Press	XY				○	○	○	
	Laser Cutting Mathine	XY				○	○		
		Z				○	○		
	Wood Working Machine					○	○	○	○
Machines of General use and special Use					○	○	○	○	○
Semiconductor Machines	Explosure Equipments		○	○					
	Chemical Treatment					○	○	○	○
	Wire Bonder			○	○	○			
	Prober		○	○	○	○			
	Inserter				○	○	○	○	
	PCB Driller			○	○	○	○	○	
Industrial Robots	Orthogonal Type	As'sy		○	○	○	○	○	
		Others					○	○	○
	Muliti-joints Type	As'sy			○	○	○		
		Others				○	○	○	
	SCARA Type				○	○	○	○	
Machines for Steel molding							○	○	○
Injection Molding Machines							○	○	○
Three-Dimensonal Measuring Machines			○	○	○				
Business Machines							○	○	○
Patterm Image Machines			○	○					
Nuclear	Rod Control					○	○	○	
	Mechnaical Snubber							○	○
Aircrafts						○	○		

1-8-2 Countermeasure Against Thermal Displacement

Thermal displacement of the screw shaft results in deterioration of the positioning accur acy.

The magnitude of the thermal displacement is calculated as follows :

$\triangle \ell = \alpha \cdot \triangle t \cdot L$

$\triangle \ell$: Thermal displacement

α : Coefficient of thermal expansion

$\triangle t$: Temperature rise (deg) at screw shaft

L : Screw shaft length

Namely, the screw shaft develops elongation of 12 μm per 1m when the temperature rises by 1°C. The ball screw, which lead has been machined to high accuracy, may fail to meet high level requirments because of the thermal displacement due to temperature rise. As the ball screw is operated at higher speeds, the heat generation grows to increase the influence of temperature.

The thermal displacement countermeasures for ball screws include the following :

(1) Control of heat generation

- Optimization of preload
- Correct selection and supply of lubricant
- Increase in ball screw lead, with reduced rotation speed

(2) Forced cooling

- Hollow screw shaft to allow cooling fluid to flow through
- Cooling of screw shaft exterior with cooling oil or air

(3) Aviod influence of temperature rise

High-speed warming up for use in a temperature stabilized size :

- Operates after the temperature become stable
- Pre-tension od screw shaft
- Negative travel compensation of cumulative lead
- Use of closed loop

1-9 Life Design

1-9-1 Life of Ball Screws

Even the ball screw is used under correct conditions, it would still fail after a period of time due to deteriotation. The elapse of time until is out of service is called the service life of the screw, which is generally classified into the fatigue life when delamination phenomenon occurs and the accuracy deterioation life caused by wear-out, etc.

1-9-2 Basic Static Load Rating Coa

The basic load rating is an axial static load which will produce a permanent deformation at contact points of the balls to ball grooves equal to 0.01% of ball diameter.

1-9-3 Basic Dynamic Load Rating Ca

The basic dynamic load rating is an axial load which allow 90% of a group of identical ball screws (rotated under the same condition) to rotate without flaking for 10^6 revolutions.

This basic dynamic load rating is shown in the table of dimensions.

Relation between load and service life $L_\alpha = \left(\frac{1}{P}\right)^3$ L : Service life P : Load

1-9-4 Fatigue Life

Average load Pe

(1) When axial load keeps changing from time, please calcuate in order to find out the average load for the equivalent fatigue life under different load condition changes. (see Table 1.9.1)

$$Pe = \left(\frac{P_1^3 n_1 t_1 + P_2^3 n_2 t_2 + \ldots + P_n^3 n_n t_n}{n_1 t_1 + n_2 t_2 + \ldots + n_n t_n}\right)^{\frac{1}{3}} \text{(kgf)}$$

Axial Load (kgf)	Rotating Speed (min^{-1})	Time(%)
P_1	n_1	t_1
P_2	n_2	t_2
:	:	:
P_n	n_n	t_n

But, $t_1 + t_2 + t_3 + \ldots + t_n = 100$

Table 1.9.1 Service Life in Different Application.

Usage	Life in hours (h)
Working machines	20000
General industrial machines	10000
Automatic control machines	15000
Measurement machines	15000

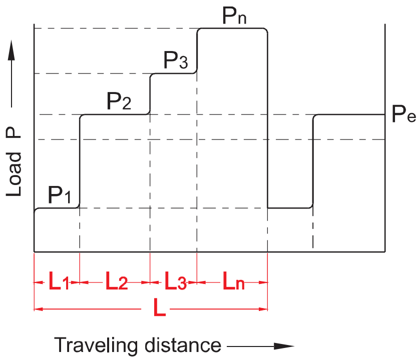


Fig 1.9.1

$$P_e = \frac{2P_{max} + P_{min}}{3} \text{ (kgf)}$$

P_{max} : Maximal axial load (kgf)

P_{min} : Minimal axial load (kgf)

(2) When load changes according to sine curve (see Fig 1.9.2)

$P_e \fallingdotseq 0.65\, P_{max}$ ..... (Fig A)

$P_e \fallingdotseq 0.75\, P_{max}$ ..... (Fig B)

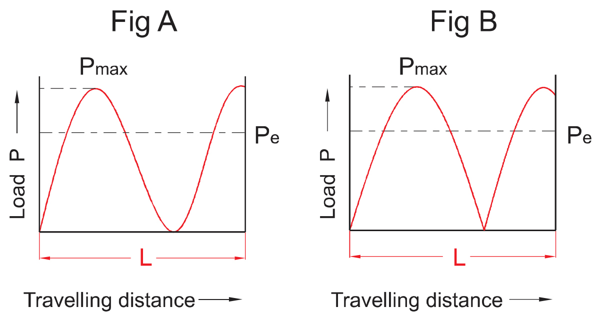


Fig 1.9.2

1-9-5 Calculation of Life

The fatigue life is generally expressed by the total number of revolutions. The total rotation hours or total travel distance may also be used to express life. The fatigue life is calualated as follow :

$$L = \left(\frac{C_a}{P_a \cdot f_w} \right)^3 \cdot 10^6 \qquad L_t = \frac{L}{60n} \qquad L_s = \frac{L \cdot \ell}{10^6}$$

Where

L : Rated fatigue life (rev)

L_s : Life in travel distance (km)

P_a : Axial (kgf)

f_w : Load factor (Factor depending on operation conditions)

L_t : Life in hours (h)

C_a : Basic dynamic load rating (kgf)

n : Rotating speed (rpm)

ℓ : Lead (mm)

Table 1.9.2 Load Factor (f_w)

Vibration and impact	Velocity (V)	f_w
Very Slight	Very Low $V \leqq 0.25$ m/s	1~1.2
Slight	Low $0.25 < V \leqq 1$ m/s	1.2~1.5
Moderate	Medium $1 < V \leqq 2$ m/s	1.5~2
Strong	High $V > 2$ m/s	2~3.5

Table 1.9.3 Factor of Safety (f_s)

Usage	Operation	f_s
Industrial machines	Normal operation	1.0 ~ 1.3
	Operation with impact and vibration	2.0 ~ 3.0
Work machines	Normal operation	1.0 ~ 1.5
	Operation with impact and vibration	2.5 ~ 7.0

Basic Dynamic Load Rating Ca

$C_a = P_e \cdot f_s$

Basic Static Load Rating Coa

$C_{oa} = P_{max} \cdot f_s$

Key Points for Ball Screws Selection

When ball screws are subjected to selection, it is a most fundamental rule that you must first clearly find out what the operation conditions are before going ahead with the final design. Moreover, the elements of your selection include load weight, stroke, torque, position determination accuracy, tracking motion, hardness, lead stroke, nut inside diameter, etc., all elements are mutually related, any change to one of the elements will lead to the changes of other elements, special attention should always be paid to the balance among the elements.

1. Setting of operation conditions

(a) Machine service life time reckoning of H (hr)

H = [ ] hours／day · [ ] days／year · [ ] life years · [ ] Running

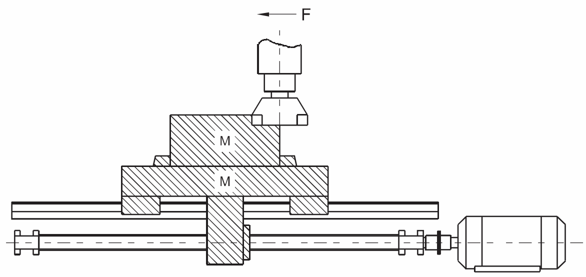
(b) Mechanical conditions

calculation Date / Difference Operations	Speed/rotations	Cutting resistance	Sliding resistance	Time used
Fast feed	m／min／min^{-1}	kgf	kgf	%
Light cutting	／			
Medium cutting	／			
Heavy cutting	／			

(c) Position determination accuracy

Feed accuracy error factor includes load accuracy and system rigidity. Thermal displacement due to heat generation and positional error of the guide system are also important factors.

Calculation for Ball Screws Selection



Design conditions

1. Working table weight 300 Kg
2. Working object weight 400 Kg
3. Maxima 700 mm
4. Fast feed speed 10 m／min
5. Minimal disassembly ability 10 μm／stroke
6. Driving motor DC motor (MAX 1000 min^{-1})
7. Guiding surface friction coefficient (μ = 0.05~0.1)
8. Running rate 60 %
9. Accuracy review items
10. Inertia generated during acceleration/deceleration can be neglected because the time periods involved are comparatively small.

1. Setting of operation conditions

(a) Machine service life time reckoning of H (hr)

H = 12 hr · 250 days · 10 years · 0.6 Running

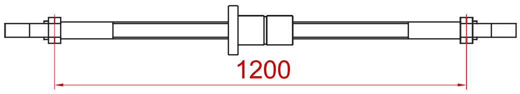
= 18000 hr

(b) Mechanical conditions

calculation Date / Difference Operations	Speed/rotations	Cutting resistance	Sliding resistance	Time used
Fast feed	10 m／min／1000 min^{-1}	0 kgf	70 kgf	10 %
Light cutting	6／600	100	70	50
Medium cutting	2／200	200	70	30
Heavy cutting	1／100	300	70	10

Sliding resistance = (300 + 400) · 0.1 = 70 kgf

Key Points for Ball Screws Selection	Calculation for Ball Screws Selection
2. Ball screw lead stroke ℓ (mm) $\ell = \frac{\text{Fast feed stroke (m/min)} \cdot 1000}{\text{Max. Rotating speed (min}^{-1}\text{) of motor}}$ (mm)	2. Ball screw lead stroke ℓ (mm) $\ell = \frac{10000}{1000} = 10$ (mm) Minimal disassembly = $\frac{10\text{mm}}{1000 \text{ stroke}}$ = 0.01 mm／stroke
3. Computation of average load Pe (kgf) $P_e = \left(\frac{P_1^3 n_1 t_1 + P_2^3 n_2 t_2 + \ldots + P_n^3 n_n t_n}{n_1 t_1 + n_2 t_2 + \ldots + n_n t_n} \right)^{\frac{1}{3}}$ $P_e = \frac{2P_{max} + P_{min}}{3}$ $P_e \fallingdotseq 0.65 P_{max}$ $P_e \fallingdotseq 0.75 P_{max}$	3. Computation of average load Pe (kgf) $P_e = \left(\frac{70^3 \cdot 1000 \cdot 10 + 170^3 \cdot 600 \cdot 50 + 270^3 \cdot 200 \cdot 30 + 370^3 \cdot 100 \cdot 10}{1000 \cdot 10 + 600 \cdot 50 + 200 \cdot 30 + 100 \cdot 10} \right)^{\frac{1}{3}}$ $= \left(\frac{31.7 \cdot 10^{13}}{4.7 \cdot 10^4} \right)^{\frac{1}{3}}$ $\fallingdotseq$ 189 kgf
4. Average number of rotations n_m $n_m = \frac{n_1 t_1 + n_2 t_2 + \ldots + n_n t_n}{100}$	4. Average number of rotations n_m $n_m = \frac{1000 \cdot 10 + 600 \cdot 50 + 200 \cdot 30 + 100 \cdot 10}{100}$ $= \frac{4.7 \cdot 10^4}{100} = 470 \text{ min}^{-1}$
5. Calculation of required dynamic rated load Ca Ca = Pe • fs	5. Calculation of required dynamic rated load Ca Ca = 189 • 5 = 945 (kgf)
6. Calculation of required static rated load Coa Coa = Pmax • fs	6. Calculation of required static rated load Coa Coa = 369 • 5 = 1845 (kgf)
7. Selection of nut type Ca＞945　Coa＞1845 Select the nut types with basic dynamic rated load and and basic static rated load as specified above.	7. Selection of nut type Choose SFNI 2510 on the catalogue Ca = 2954 (kgf) Coa = 7295 (kgf)

Key Point for Ball Screws Selection	Calculation for Ball Screws Selection
8. Calculation of life confirmation Lt (h) $L_t = \frac{L}{60n} = (\frac{C_a}{P_e \cdot f_w})^3 \cdot 10^6 \cdot \frac{1}{60n}$	**8. Calculation of life confirmation Lt (h)** $L_t = (\frac{2954}{189 \cdot 2})^3 \cdot 10^6 \cdot \frac{1}{60 \cdot 470} = 42544(h)$
9. Mounting distance of screw length	**9. Mounting distance of screw length**  (Fixed)(BK17) (Fixed)(BK17)
10. Determination of screw length Screw length = Maximal stroke + Nut length + Two reserved length at shaft end	**10. Determination of screw length** Screw length = 700 + 85 + 76 + 76 = 937 mm 937 mm < 1200 mm
11. Permissible axial load	**11. Permissible axial load** Omitted because of F-F support
12. Permissible revolution speed n and dm $n = \alpha \cdot \frac{60\lambda^2}{2\pi L^2}\sqrt{\frac{EIg}{\gamma A}} = f \frac{dr}{L^2} \cdot 10^7$ (rpm) dm = Shaft dia · Maximal speed	**12. Permissible revolution speed n and dm** $n = \frac{21.9 \cdot 21.86 \cdot 10^7}{1200^2} = 3324\ min^{-1} < n_{max}$ dm = 25 · 1000 = 25000 < 50000
13. Countermeasure against thermal displacement $\triangle\ell = \alpha \cdot \triangle t \cdot L$ $\triangle\ell$: Thermal displacement α : Coefficient of thermal expansion $\triangle t$: Temperature rise (deg) at screw shaft L : Screw shaft length	**13. Countermeasure against thermal displacement** It is estimated there would be a temperature rise 2~5°C with the ball screws of the general machinery, take temperature rise of 2°C to computer the extension of ball screw. $\triangle\ell = \alpha \cdot \triangle t \cdot L = 11.7 \cdot 10^{-6} \cdot 2 \cdot 700mm \fallingdotseq 0.016mm$ $F_p = \frac{EA\triangle\ell}{L} = \frac{2.06 \cdot 10^4 \cdot \frac{\pi \cdot 21.86^2}{4} \cdot 0.016}{700} \fallingdotseq 177(kgf)$

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Key Point for Ball Screws Selection

14. Rigidity

(1) Axial rigidity K_s and displacement δ_s of screw shaft

$$K_s = \frac{P}{\delta_s} \ \text{(kgf/mm)}$$

P : Axial load (kgf)

$$\delta_{SF} = \frac{PL}{4AE} \ \text{(mm)}$$ ....(with reference to page C20)

(2) Axial rigidity K_N and displacement δ_s of nut

$$\delta_{NS} = \frac{K}{\sin\beta}\left(\frac{Q^2}{d}\right)^{\frac{1}{3}} \cdot \frac{1}{\zeta} \ \text{(mm)}$$

$$Q = \frac{P}{n \cdot \sin\beta} \ \text{(kgf)}$$

$$n = \frac{D_0 \pi m}{d} \ \text{(each)}$$ ....(with reference to page C21)

(3) Axial rigidity K_B and displacement δ_B of bracing shaft

$$K_B = \frac{P}{\delta_B} \ \text{(kgf/mm)}$$ ....(with reference to page C22)

Calculation for Ball Screws Selection

14. Rigidity

Deviation can be corrected by estimating the temperature rise per extension of 0.016 mm, and taking into consideration of the pre-tension of 177 kgf.

(1) Directional rigidity

$$\delta_{SF} = \frac{PL}{4AE} = \frac{27 \cdot 1200}{4 \cdot \frac{\pi \cdot 21.86^2}{4} \cdot 2.06 \cdot 10^4}$$

$$= 0.00105 \ \text{(mm)}$$

$$K_s = \frac{370}{0.00105} = 3.5 \cdot 10^5 \ \text{kgf/mm}$$

(2) Rigidity of steel ball and nut groove

$$n = \frac{26.62 \cdot \pi \cdot 4}{4.762} = 70$$

$$Q = \frac{370}{70 \sin 45^\circ} = 10$$

$$\delta_{NS} = \frac{0.00057}{\sin 45^\circ}\left(\frac{10^2}{4.762}\right)^{\frac{1}{3}} \cdot \frac{1}{0.7}$$

$$= 3.2 \cdot 10^{-3} \ \text{mm}$$

$$K_N = \frac{370}{3.2 \cdot 10^{-3}} = 1.27 \cdot 10^5 \ \text{kgf/mm}$$

(3) Rigidity of support bearings

Where, nut rigidity 50 kgf/μm

$$\delta_B = \frac{370}{51 \cdot 2} = 3.6 \ \mu\text{m}$$

$$K_B = \frac{370}{0.0036} = 1 \cdot 10^5 \ \text{kgf/mm}$$

- $\delta_{TOTAL} = 1.05 + 3.2 + 3.6 = 7.85 \ \mu$m

Key Point for Ball Screws Selection

15.Confirmation of the ball screw life

Calculation for Ball Screws Selection

15.Confirmation of the ball screw life

L = 42544 (h) $>$ 18000 (h)

1-10 Cautions About Use of Ball Screws

Ball screw assemblies are delicate components therefore; extra care must be taken to prevent the ball track from small particle and damages that caused by edged component or tools. Disassembling ball screw assembly without guidance or over travelling are strongly prohibited, if dismantle occurs, permanent damage will take place, please contact TBI Motion for after service. (as per Fig 1.10.1)

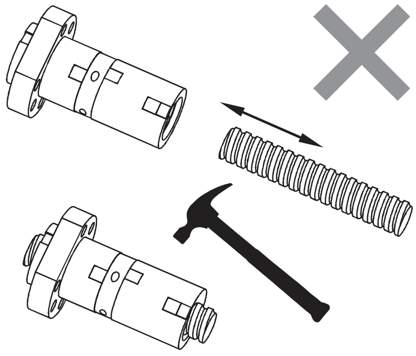


Fig 1.10.1 Error installation

If disassembling is required, use the mandrel attached to ensure that steel balls does not fall. (Please refer to page C33)

1-10-1 Lubrication

Adequate lubrication must be provided when ball screw is used, insufficient lubrication will result in contact of metal, which in turn leads to increase of friction and friction loss, thus cause failure or shortening of service life.

Lubricants applied to ball screws can be divided into 2 types, namely lubricating oil and consistent grease. In general speaking, in respect of maintenance, consistent grease will lead to increase of dynamic friction torque linearly along with increase of rotating speed, hence oil lubrication is deemed the better way when speed exceeds 3-5 m/min; however, don't forget the fact that there have been examples that using grease has been capable of achieving speed of 10 m／min, with respect to the equipment.

Table 1.10.1 Inspection of lubrication and interval of refill

Method	Interval	Check Item	Replenish or Change Interval
Auto. Intermittent oil supply	Weekly	Oil level, contamination	Add at each check, as required depending on tank level
Grease	Initially 2~3 months	Contamination on entry of chip	replenish yearly or according to the inspection result.
Oil bath	Daily	Oil level	To be determined according to consumption

1-10-2 Dust Proof／Prevention

Any foreign matter or water, if allowed to enter the ball screw, may increase friction and cause damage.For example, the entry of chips or cutting oil may be expected with machine tools depending on the work environment. Where entry of foreign matter is anticipated, use a bellows or telescopic cover as shown in Fig 1.10.2, to cover the screw shaft completely.

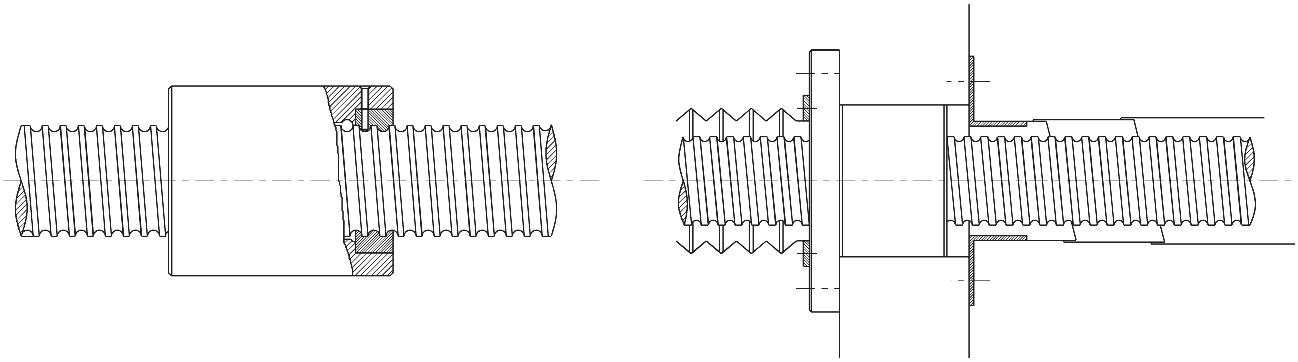


Fig 1.10.2 Dust proof Method by Telescopic Cover and Bellows

1-10-3 Offset Load

When offset load phenomenon occurs, screw life and noise tend to be directly affected, which would usually be accompanied with hand feel of rough running. In the event unload running and running right after assembling demonstrate different degree of cases, this should be ascribed to the poor assembly accuracy which will produce offset load phenomenon as shown in Fig 1.10.3

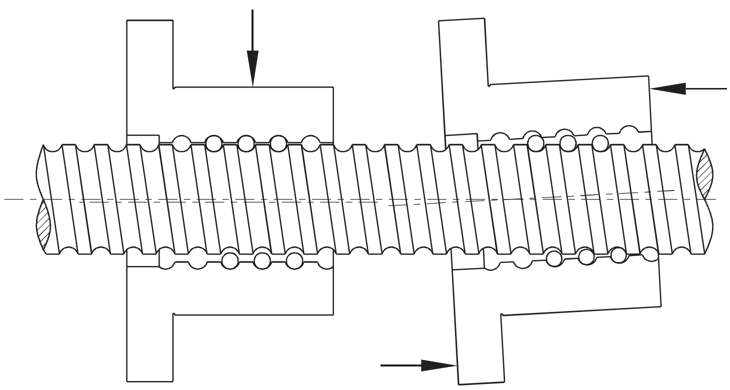


Fig 1.10.3 Offset Load

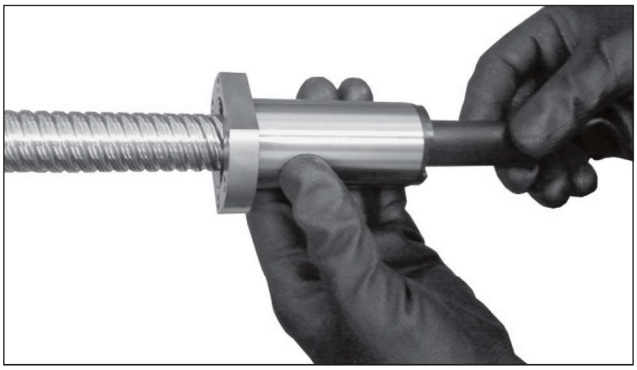
1-10-4 Assembling the Ball Screws

If ball nut is shipped un-assembled please follow the procedure as below.

Table 1.10.2 Procedure

(1) Remove the band.

(2) Attached the mandrel towards machine ends.



(3) Rotate the ball nut into the screw along the thread.

(4) Ensure that the ball nut is fully inserted before remove the mandrel.

1-10-5 Machining Specifications

(1) For the Ball Screws with internal ball circulation ball nut, it is required to have at least one end with complete thread to the end of screw, it is also required to have the journal area is with diameter to be smaller than the diameter of thread root as Fig 1.10.4 shown.

(2) The thread on screw shaft are hardened by induction hardening. It shall cause about 10~20mm at both ends journal purpose. The unhardened area will be labeled.

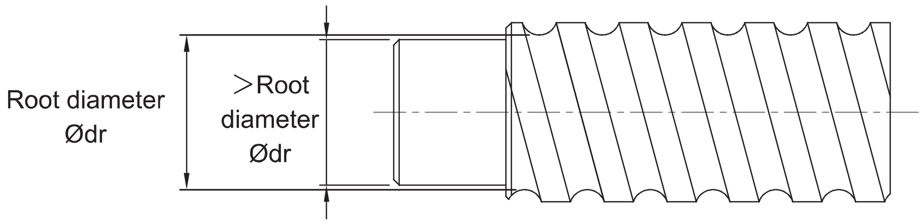


Fig 1.10.4 For Internal Circulation

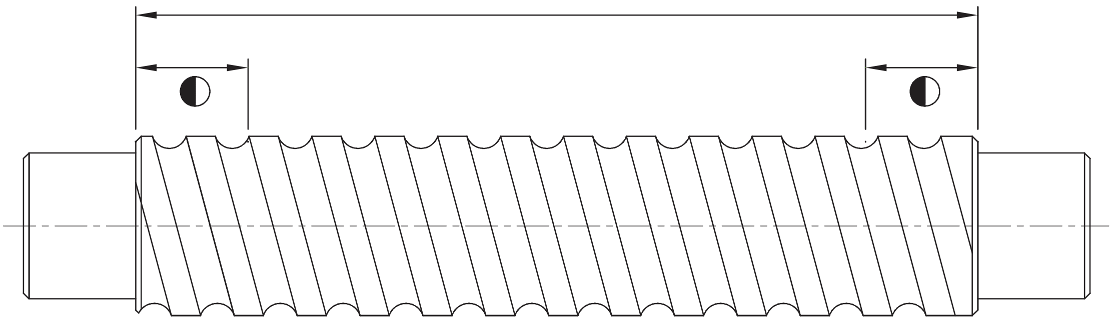


Fig 1.10.5 Harden Area

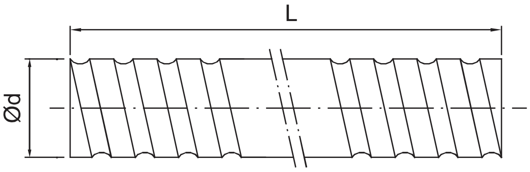


Fig 2.1.1 Screw Shaft Nominial Diameter

Table 2.1.1 Ground Ball Screw Specifications Ø4~32

Unit：mm

Model No.			Accuracy Grade	Threading Direction	Number of Grooves	Standard Code of Shaft	Type of Nut
Ød	l	Ball Diameter		R : Right L : Left			
4	1	0.8	C7, C5, C3	R	1	SCR00401	K
6	1	0.8	C7, C5, C3	R	1	SCR00601	K
8	1	0.8	C7, C5, C3	R／L	1	SCR00801	K
	2	1.2	C7, C5, C3	R／L	1	SCR00802	K
	2.5	1.2	C7, C5, C3	R	1	SCR0082.5	K, BSH
10	2	1.2	C7, C5, C3	R／L	1	SCR01002	K, BSH
	4	2	C7, C5, C3	R	1	SCR01004	K, BSH
12	2	1.2	C7, C5, C3	R／L	1	SCR01202	K
	4	2.5	C7, C5, C3	R	1	SCR01204	NU, BSH
	5	2.5	C7, C5, C3	R	1	SCR01205-A	V, NU, BSH, H
	5	2.5	C7, C5, C3	R	1	SCR01205-B	K
	10	2.5	C7, C5, C3	R	2	SCR01210-B	V
14	2	1.2	C7, C5, C3	R／L	1	SCR01402	K
	4	2.5	C7, C5, C3	R	1	SCR01404	BSH
16	2	1.2	C7, C5, C3	R／L	1	SCR01602	K
	4	2.381	C7, C5, C3	R	1	SCR01604(N)	V, NI, NU, BSH
	5	3.175	C7, C5, C3	R／L	1	SCR01605	V, NI, NU, BSH
	10	3.175	C7, C5, C3	R／L	2	SCR01610	V, NI, NU, BSH
	16	2.778	C7, C5, C3	R	2	SCR01616	Y
	32	2.778	C7, C5, C3	R	2	SCR01632	Y
20	4	2.381	C7, C5, C3	R	1	SCR02004(N)	V, NI, NU
	5	3.175	C7, C5, C3	R／L	1	SCR02005	V, NI, NU, BSH, H
	10	3.969	C7, C5, C3	R	1	SCR02010	V
	20	3.175	C7, C5, C3	R	2	SCR02020	V, Y, H
	40	3.175	C7, C5, C3	R	2	SCR02040	Y
25	4	2.381	C7, C5, C3	R	1	SCR02504(N)	NI, NU
	5	3.175	C7, C5, C3	R／L	1	SCR02505	V, NI, NU, BSH, H
	6	3.969	C7, C5, C3	R	1	SCR02506	V, NU
	8	4.762	C7, C5, C3	R	1	SCR02508	V, NU
	10	4.762	C7, C5, C3	R	1	SCR02510-A	NI, NU, BSH
	10	6.35	C7, C5, C3	R	1	SCR02510-B	V
	25	3.969	C7, C5, C3	R	2	SCR02525	V, Y
	50	3.969	C7, C5, C3	R	2	SCR02550	Y
32	4	2.381	C7, C5, C3	R	1	SCR03204(N)	V, NI, NU
	5	3.175	C7, C5, C3	R／L	1	SCR03205	V, NI, NU, M, H
	6	3.969	C7, C5, C3	R	1	SCR03206	V, NU
	8	4.762	C7, C5, C3	R	1	SCR03208	V, NU
	10	6.35	C7, C5, C3	R／L	1	SCR03210	V, NI, NU
	20	6.35	C7, C5, C3	R	1	SCR03220	V
	32	4.762	C7, C5, C3	R	2	SCR03232	Y
	64	4.762	C7, C5, C3	R	2	SCR03264	Y

2. Kalatec Automation Ball Scre

2-1 Nominal Model Code of Ball Screw

SFU R 025 05 T4 D G C5 - 600 - P1 - B2+N3 N3

Nominal Model

S
- S : Single nut
- D : Double nut
- O : OFF set double nut

F
- F : With flange
- C : Without flange

U
- NI : NI type nut
- NU : NU type nut
- H : H type nut
- Y : Y type nut
- V : V type nut
- U : DIN nut
- M : M type nut
- K : K type nut

Threading Direction
R : Right L : Left

Nominal Diameter
Unit : mm

Lead
Unit : mm

Number of Turns (Turn · Row)
Turn : T : 1 A : 1.5 (or 1.7/1.8) B : 2.5/2.8 C : 3.5 D : 4.8
ex : (2.5 · 2 = B2)

Flange Type
N : Not cutting S : Single cutting D : Double cutting

Product Code
G : Ground F : Rolled

Accuracy Grade
C0, C1, C2, C3, C5, C7, C10

Overall Length of Shaft
Unit : mm

Axial Clearance and Preload Value
P0, P1, P2, P3, P4

Number of Nut
(Leave blank if only one nut is required) Ex : Two install two nuts in a shaft : B2

Nut Surface Treatment
S : Standard B1 : Black Oxidation N1 : Hard Chrome Plating P : Phosphating
N3 : Nickel Plating N4 : Raydent N5 : Balck Chrome Plating

Shaft Surface Treatment
S : Standard B1 : Black Oxidation N1 : Hard Chrome Plating P : Phosphating
N3 : Nickel Plating N4 : Raydent N5 : Balck Chrome Plating

※ No symbol required when no plating is need.
※ An inspection report is provided for ground ball screws with an accuracy higher than C5.

Table 2.1.2 Standard Specifications Ø4~80

Unit：mm

Model No.			Accuracy Grade	Threading Direction R : Right L : Left	Number of Grooves	Standard Code of Shaft	Type of Nut
Ød	l	Ball Diameter					
40	5	3.175	C7, C5, C3	R／L	1	SCR04005	V, NI, NU, H
	6	3.969	C7, C5, C3	R	1	SCR04006	V, NU
	8	4.762	C7, C5, C3	R	1	SCR04008	V, NU
	10	6.35	C7, C5, C3	R／L	1	SCR04010	V, NI, NU
	20	6.35	C7, C5, C3	R	2	SCR04020	V
	40	6.35	C7, C5, C3	R	2	SCR04040	Y
	80	6.35	C7, C5, C3	R	2	SCR04080	Y
50	5	3.175	C7, C5, C3	R	1	SCR05005	V, H
	10	6.35	C7, C5, C3	R／L	1	SCR05010	V, NI, NU
	20	9.525	C7, C5, C3	R	1	SCR05020	V
	50	7.938	C7, C5, C3	R	2	SCR05050	Y
	100	7.938	C7, C5, C3	R	2	SCR050100	Y
63	10	6.35	C7, C5, C3	R	1	SCR06310	V, NI, NU
	20	9.525	C7, C5, C3	R	1	SCR06320	V, NU
80	10	6.35	C7, C5, C3	R	1	SCR08010	V, NI, NU
	20	9.525	C7, C5, C3	R	1	SCR08020	V, NU

Table 2.1.3 H-type Specifications Ø12~50

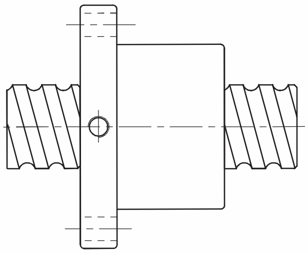
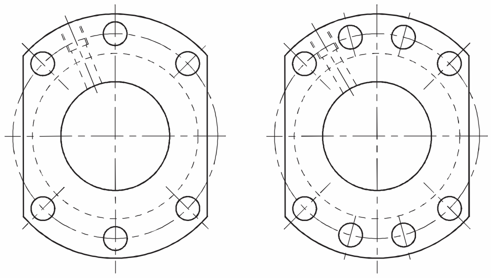
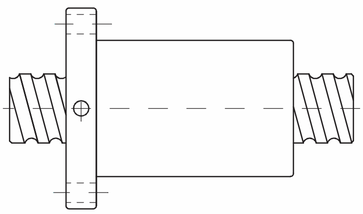
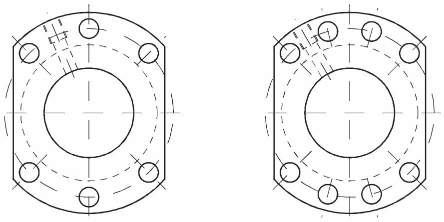
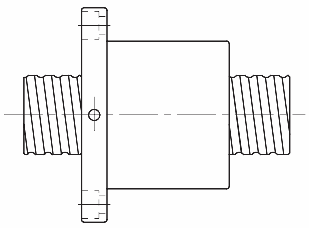
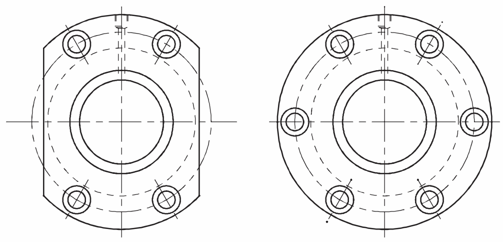
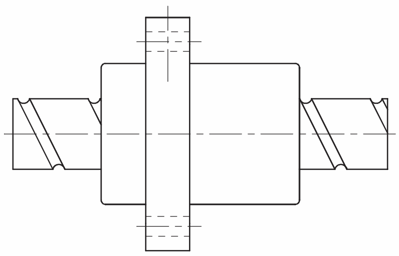
Unit：mm

Model No.			Accuracy Grade	Threading Direction R : Right L : Left	Number of Grooves	Type-H Code of Shaft	Type of Nut
Ød	l	Ball Diameter					
16	5	2.778	C7, C5, C3	R	1	SSR01605	H
	10	2.778	C7, C5, C3	R	1	SSR01610	H
	16	2.778	C7, C5, C3	R	1	SSR01616	H
20	10	3.175	C7, C5, C3	R	1	SSR02010	H
25	10	3.175	C7, C5, C3	R	1	SSR02510	H
	25	3.175	C7, C5, C3	R	1	SSR02525	H
32	10	3.969	C7, C5, C3	R	1	SSR03210	H
	20	3.969	C7, C5, C3	R	1	SSR03220	H
40	10	6.35	C7, C5, C3	R	1	SSR04010	H
50	10	6.35	C7, C5, C3	R	1	SSR05010	H

※The information is for standard production, if other needs please contact Kalatec Automation.

2-2 Precision Ground Ball Screw Series

2-2-1 Kalatec Automation Nut of Precision Ground Ball Screw Type

	Nut Type	Flange Type
NU／U (Strong dust-proof type)	SFNU／SFU  C45	 d≦32 d≧40
OFU／U (OFF set double nut)	OFU／DFU  C46	
V (High Load External Circulation type)	SFV  C49	
Y (High DM-N Rating)	SFY  C51