# 6

## Ball Screw

## 6.1 Technological description of Ball Screws

### 6.1.1 Lead / Travel Accuracy

#### Accuracy

1. Lead accuracy of ABBA Ball screws (grade C0~C5) is specified in 4 basic terms (E, e, $e_{300}$, $e2\pi$). There are defined in Fig.6.1.1.1 Tolerance of deviation (± E) and variation (e) of accumlated reference travel are shown in Table 6.1.1.1~ 6.1.1.3

2. 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 as $e_{300}$ of table 6.1.1.3 They are 0.05mm for C7 and 0.21mm for C10.

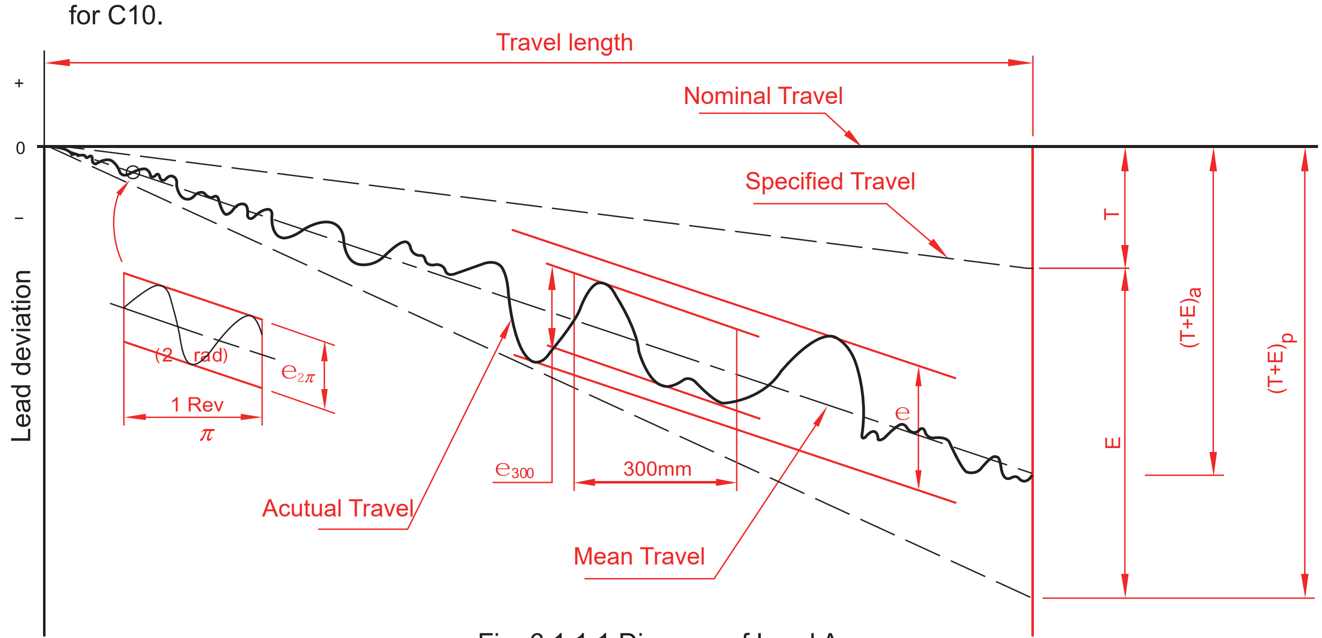



Fig. 6.1.1.1 Diagram of Lead Accuracy

**Table 6.1.1.1 Definition of Terms of Lead Accuracy**

| | | |
|---|---|---|
| T+E | Cumulative Traval lead | It's a straight line, it represents the tendency of actual cumulative lead. This is the data after laser detection calculated by the method of least squares. |
| P | | Allowable value |
| a | | Actual measured value. |
| T | Travel Compensation | Travel compensation is the difference between specified and nominal travel within the useful travel. A slightly smaller value compared to 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.<br>Note: If no compensation is needed, specified travel is the same as nominal travel. |
| E | Mean Travel Deviation | Mean Travel deviation is the difference between Mean Travel and Specified travel within travel length |
| e | Travel Variations | Maximum width of variation over the travel length. |
| $e_{300}$ | | Actual width of variation for the length of 300mm taken anywhere within the travel length. |
| $e_{2\pi}$ | | Wobble error, actual width of variation for one revolution($2\pi$ radian) |

Table 6.1.1.2 Mean Travel Deviation (± E) and Travel Variation (e) (JIS B 1192)

| 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 | | | 32 | 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 | 62 | 210 | 115 | | |
| 8000 | 10000 | | | | | | | | | 260 | 140 | | |
| 10000 | 12500 | | | | | | | | | 320 | 170 | | |

Table 6.1.1.3 Variation per 300mm (e300) and Wobble Error (e2π) (JIS B 1192)

Unit : μm

| Grade | C0 | C1 | C2 | C3 | C5 | C7 | C10 |
|---|---|---|---|---|---|---|---|
| $e_{300}$ | 3.5 | 5 | 7 | 8 | 18 | 50 | 210 |
| $e_{2\pi}$ | 3 | 4 | 4 | 6 | 8 | | |

## 6.1.2 Backlash in the Axial direction ( customer demand )

The preload grade of the axial clearance of the standard ball screw

### 6.1.2.1 Maximum Backlash in the Axial direction (P0)

Unit : mm

| Maximum Backlash in the Axial direction | |
|---|---|
| Screw Shaft OD | Maximum Backlash in the Axial direction of Rolled Ball Screw |
| 4mm~14mm | 0.05 |
| 15mm~50mm | 0.08 |
| 50mm~80mm | 0.12 |

### 6.1.2.2 Maximum Backlash in the Axial direction (P1)

Unit : mm

| Maximum Backlash in the Axial direction | |
|---|---|
| Screw Shaft OD | Maximum Backlash in the Axial direction of Rolled Ball Screw |
| 4mm~80mm | 0 |

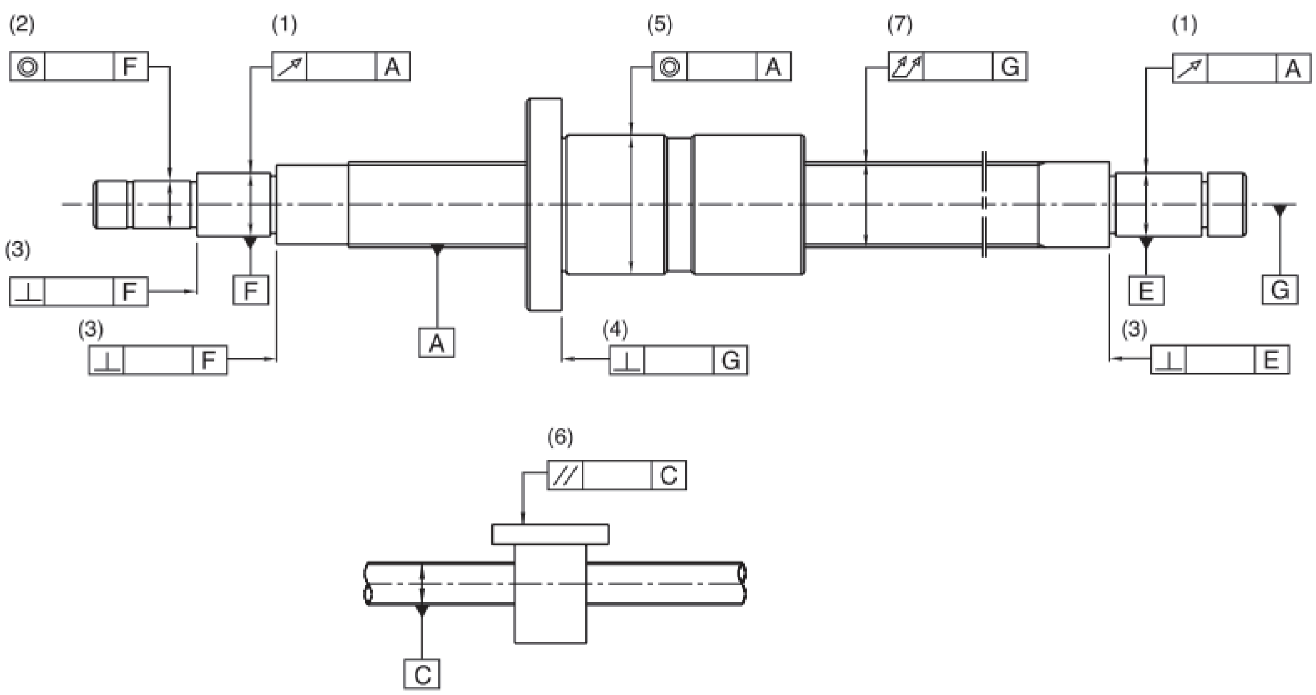
## 6.1.3 Definition of the geometric tolerance of the ball screw

To use a ball screw properly dimensional accuracy and tolerances are most important

1. With respect to the axis A of the thread groove surface, the radial runout value of the screw support part is measured.
2. Measure the coaxiality of the part mounting part with respect to the axis F of the screw support part.
3. The right angle of the end surface of the supporting part is measured with respect to the axis E of the supporting part of the screw shaft.
4. With respect to the screw axis G, measure the right angle of the reference surface of the nut or the mounting surface of the flange.
5. With respect to the screw axis A, the coaxiality of the outer periphery of the nut (cylindrical type) is measured.
6. Measure the parallelism of the outer edge of the nut (flat-head type mounting surface) with respect to the screw axis C.
7. The total yaw value in the radial direction of the screw shaft axis.

The accuracy items mentioned here are based on JIS B1192~1997. .

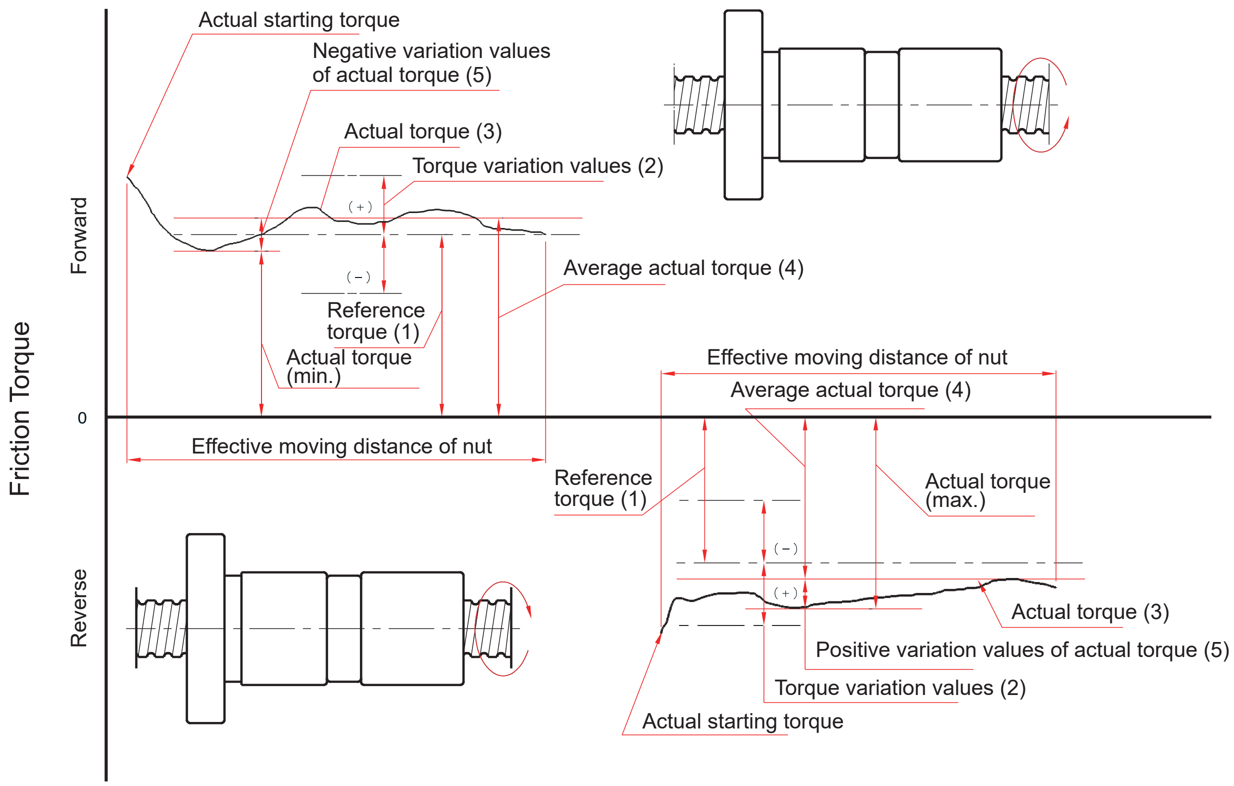
### Mounting accuracy and tolerances



# 6.1.4 Preload torque

- Terms in relation to the preload torque generated during the rotation of the preload ball screws are shown in 6.1.4.1.
- Permissible ranges of torque variation rates is shown in 6.1.4.2.

## 6.1.4.1 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 continously rotating the screws shaft or the nuts under unload condition after the specified preload has been applied upon the ball screws.

### (3) Reference

The targeted preload dynamic torque.

### (4) Torque variation values

The variation values of the targeted preload torque variation rates are specified generally based on JIS standard as.

### (5) Torque variation rate

The rate of variation values in relation to the reference 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 exercising reciprocating movements.

### (8) Actual torque variation values

The maximum 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 to the average actual torque.

## 6.1.4.2 Permissible ranges of torque variation rates

| Reference torque kgf • cm | | Effective threading length (mm) | | |
|---|---|---|---|---|
| | | Below 4000 | | 4000~10000 |
| | | Slenderness 1 : below 40 | Slenderness 1 : 40 ~ 1 : 60 | – |
| | | Grade | Grade | Grade |
| Over | Incl. | C5 | C5 | C5 |
| 2 | 4 | ±50% | ±60% | - |
| 4 | 6 | ±40% | ±45% | - |
| 6 | 10 | ±35% | ±40% | ±45% |
| 10 | 25 | ±30% | ±35% | ±40% |
| 25 | 63 | ±25% | ±30% | ±35% |
| 63 | 100 | ±20% | ±25% | ±30% |

**Note:**
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, ABBA specifications will apply.

### Calculation of reference torque Tp

The formula for computing reference torque (kgf • cm) of the ball screws is given in following :

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

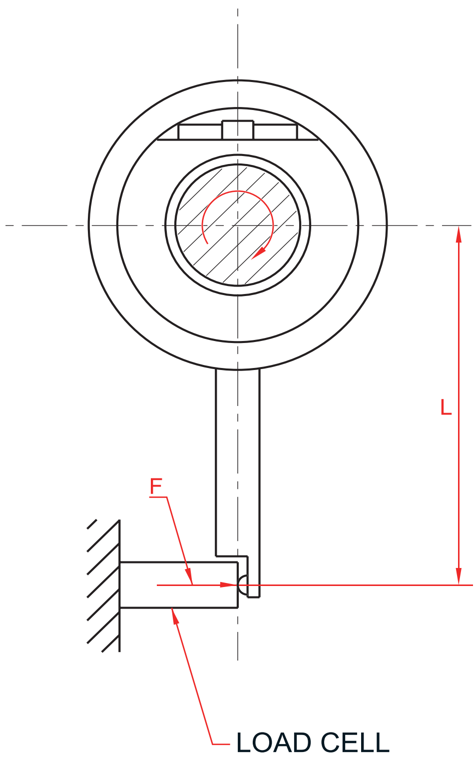
Where, Fao : Preload (Kgf)
$\beta$ : Lead angle
$\ell$ : Lead (cm)

### Measurement conditions

The preload dynamic torque Tp is determined first by adopting the following measurement conditions together with the method illustrated in the right diagram 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 Tp.

$$Tp = F \cdot L$$

Measure conditions
(1) Measurement is executed under the condition of not attaching with scraper.
(2) The rotating speed during measurement maintains at 100 rpm.
(3) According to JSK 2001 (industrial lubrication oil viscosity classificaiton standards), the lubrication oil used should be in compliance with ISO VG68.



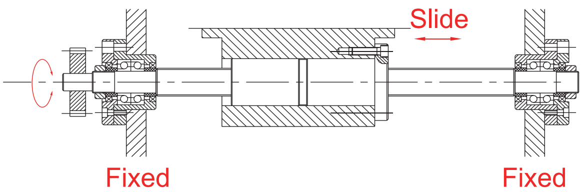

Preload dynamic torque measuring method

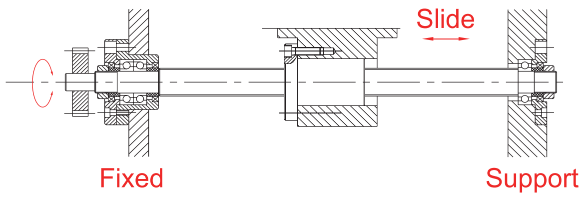
# 6.2 Screw shaft design

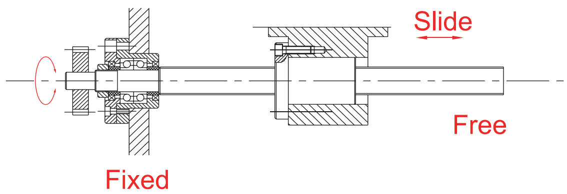
## 6.2.1 Mounting methods

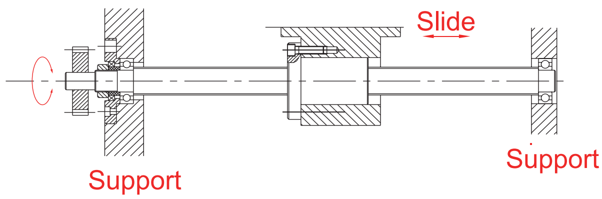
Both the critical speed and column bucking load depend upon the method of mounting and the unsupported length of the shaft, the most common mounting methods for ball screws are shown below.

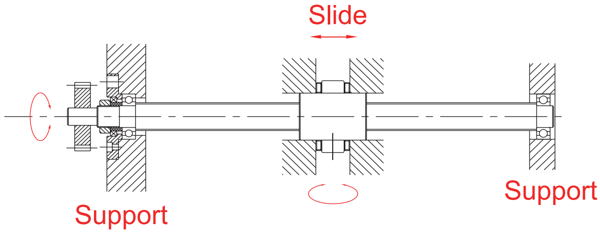
**Most common mounting methods for ball screws**

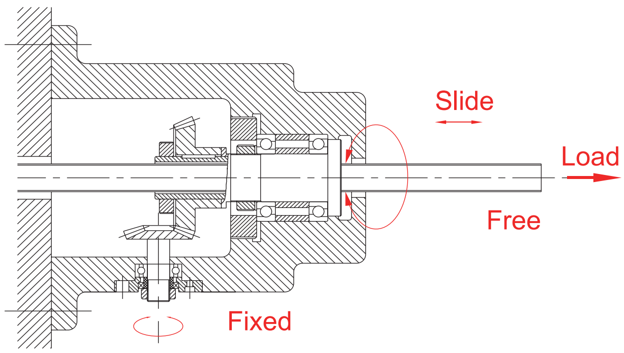


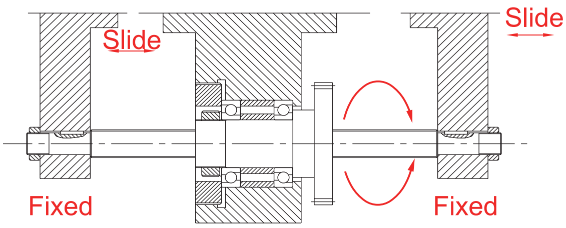



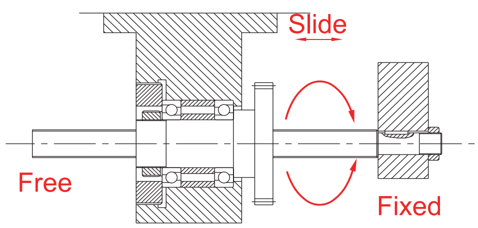



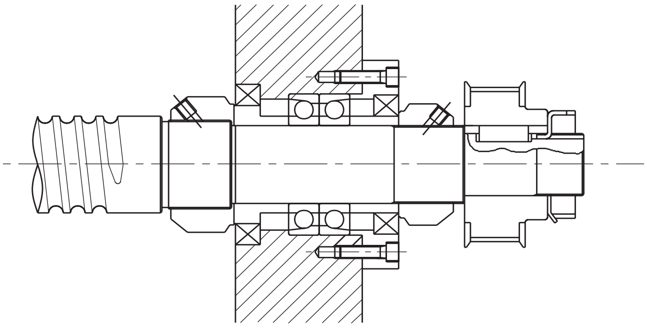



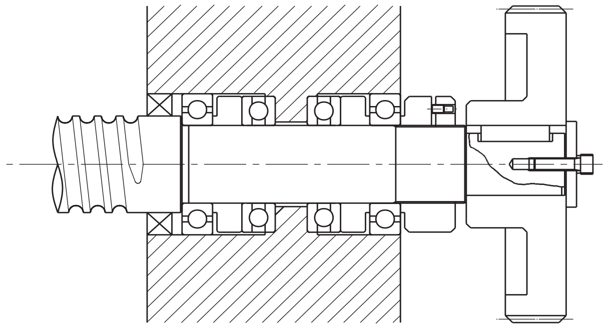



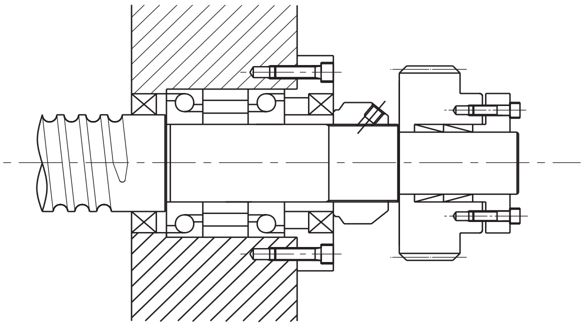



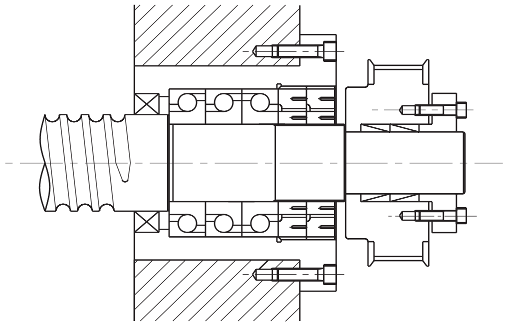



## Most machines mounting methods for ball screws

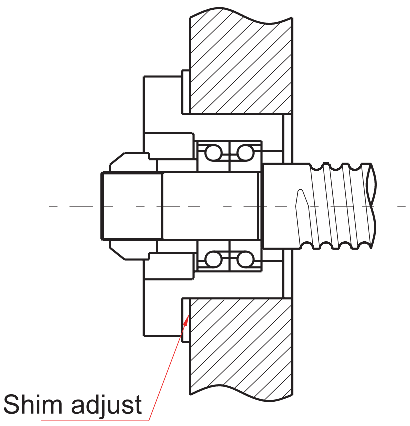


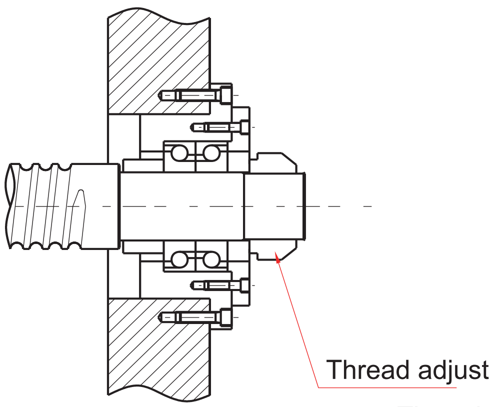


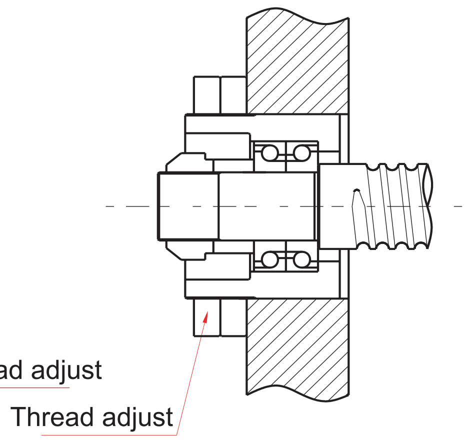




## Most common mounting methods for ball screws



# 6.2.2 Buckling 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. The diagram below summarizes the allowable compressive load for buckling for each nominal outside diameter of screw shaft. (Calculation with the equation shown right when the nominal outside diameter of the screw shaft exceed 125mm.) Select the graduation of allowable axial load according to the method of ball screw support.

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

Where,

$\alpha$ : Safety factor (0.5)

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

I : Min. secondary moment of screw shaft sectional area

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

dr : Screw shaft root diameter (mm)

L : Mounting distance (mm)

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

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

## 2 Allowable tensile compressive stress

When the mounting distance is short, please check the following two items which are irrelevant to the mounting method.

- Check the allowable tensile / buckling load (the formula shown below)
- Allowable load of the ball groove

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

Where, $P = \sigma \cdot A = \sigma \cdot \pi \cdot dr^2/4$

$\sigma$ : Allowable tensile compressive stress ( $kgf/mm^2$ )

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

dr : Screw shaft root diameter (mm)

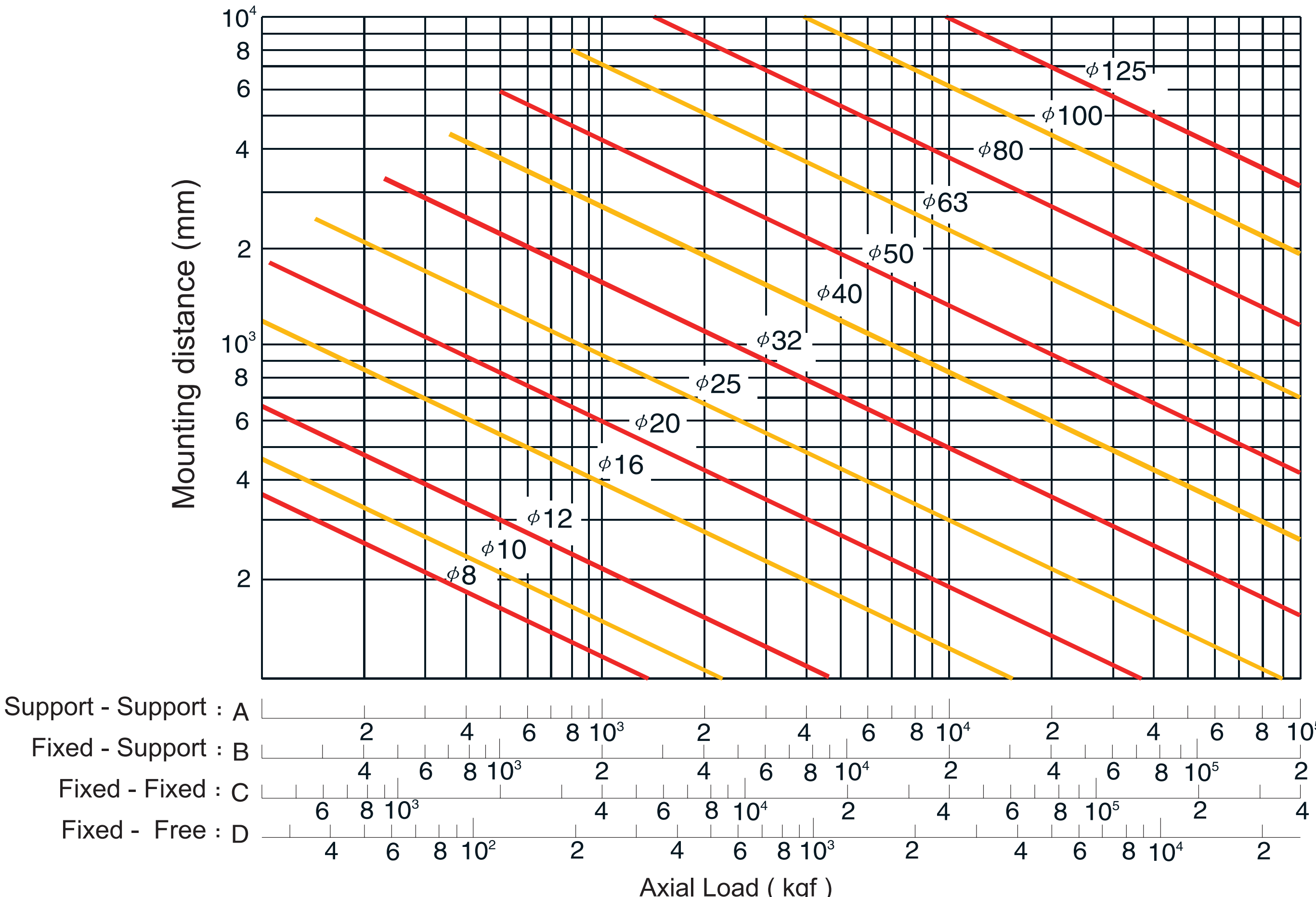



Fig. 6.2.2.1 Allowable buckling load for frustration

## 1 Critical speed

It is necessary to check if the Ball Screw rotation speed is resonant with the natural frequency of the screw shaft.
ABBA has determined 80% or less of this critical speed as an allowable rotation speed. The diagram below summarizes the allowable rotation speed of 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 general industry (Ground) dm.n≦50,000
High lead seires dm.n≦ 130,000

Product exceeding the above limits can be produced, please contact ABBA.

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

Where,

- n : Allowable rotation speed (rpm)
- $\alpha$ : Safety factor (0.8)
- E : Vertical elastic modules ( $E = 2.1 \times 10^4 kgf/mm^2$ )
- I : Min. secondary moment of screw shaft sectional area $I = \frac{\pi dr^4}{64} mm^4$
- dr : Screw shaft root diameter (mm)
- g : Acceleration of gravity ( $g = 9.8 \times 10^3 mm/s^2$ )
- $\gamma$ : Density ( $\gamma = 7.8 \times 10^{-6}$ kgf / $mm^3$ )
- A : Screw shaft sectional area ( $A = \pi dr^2/4\ mm^2$ )
- L : Mounting distance (mm)
- $f$、$\lambda$ : Coefficient determined from the Ball Screw mounting method

| | | |
|---|---|---|
| Support - Support | $f = 9.7$ | ( $\lambda = \pi$ ) |
| Fixed - Support | $f = 15.1$ | ( $\pi = 3.927$ ) |
| Fixed - Fixed | $f = 21.9$ | ( $\pi = 4.730$ ) |
| Fixed - Free | $f = 3.4$ | ( $\pi = 1.875$ ) |

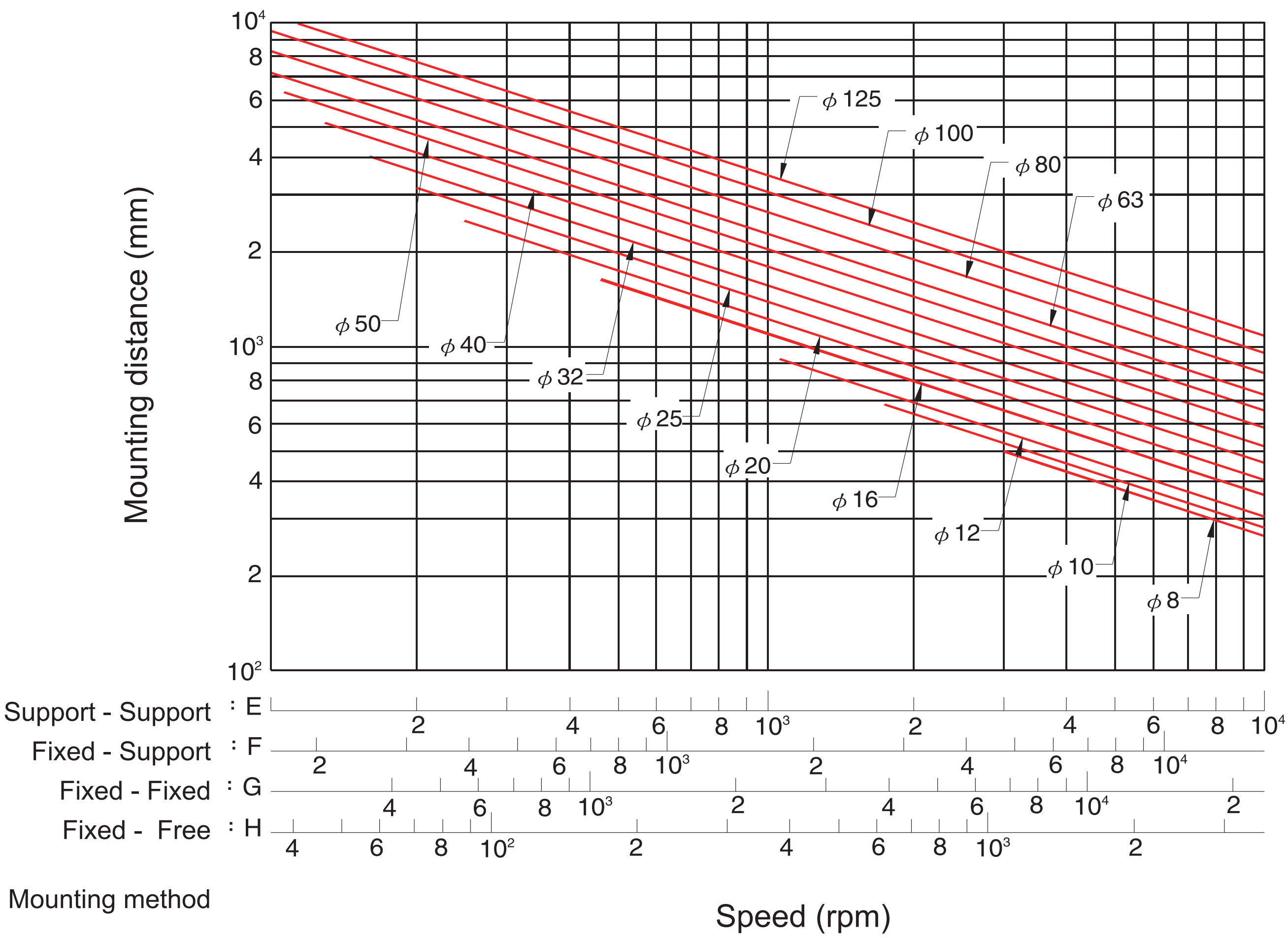



Fig. 6.2.3.1 Critical speed V.S. Shaft Dia.

# 6.3 Nut design

## 6.3.1 Selection of nut

The mounting method is an important item when selecting the appropriate Ball Screw specifications. The following are installation examples. When the conditions of use need to be judged under stricter conditions or whenjudgment conditions are unknown due to special mounting method is used , please contact ABBA.

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.

(a) External circulation type

- Economy
- Suitable for mass production
- Applicable to those with larger lead / the outside diameter of the screw

(b) Internal circulation type

- With nuts of finely crafted outside diameter (occupying small space)
- Applicable to those with smaller lead / the outside diameter of the screw

(c) High lead type

- High Speed, High DN Value
- Low Noise, Environmental protection
- Small size, Space saving

3 **Number of loop circuits**

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

4 **Shape of flanges**

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.

### 6.3.1.1 External ball circulation nuts

**Feature**

1 Offers smoother ball running

2 Offers better solution and quality for long lead or large diameter Ball Screws

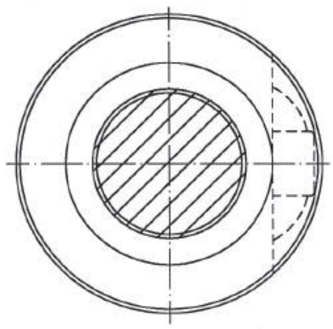


Fig. 6.3.1.1 Immersion type

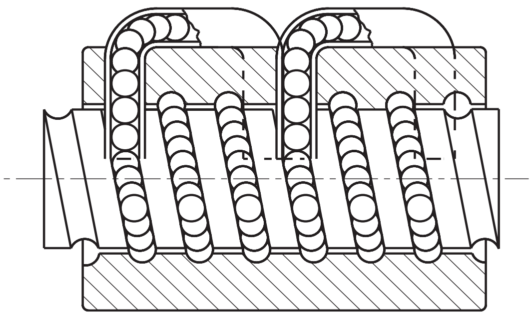


Fig. 6.3.1.2 Enternal ball circulation's nut

## 6.3.1.2 Internal ball circulation nuts

### Feature

The advantage of internal ball circulation nut is that the outer diameter is smaller than that of external ball circulation nut (Fig.6.3.1.3). Hence it is suitable for the machine with limit space for Ball Screw installation.
It is strictly required that there is at least one end of screw shaft with complete threads. Also the rest area next to this complete thread must be with smaller diameter than the nominal diameter of the screw shaft. Above are required for easy assembling the ball nut onto the screw shaft.

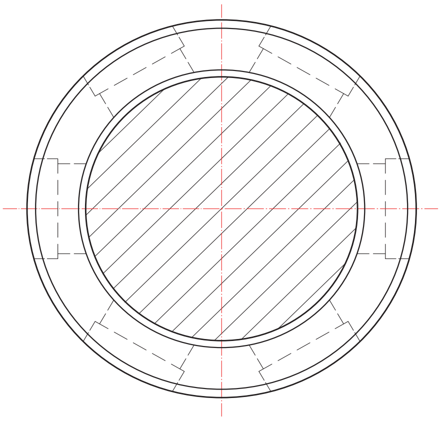


Fig. 6.3.1.3 Internal ball circulation's side view

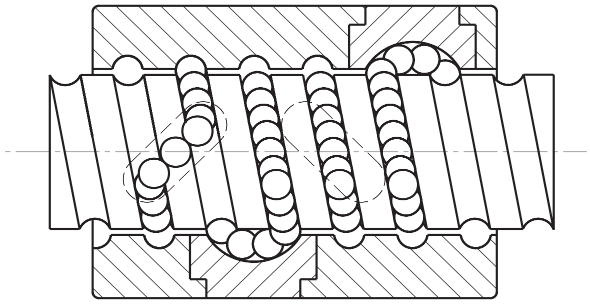


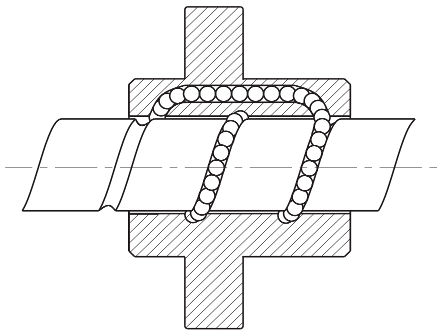
Fig. 6.3.1.4 Internal ball circulation's nut

## 6.3.1.3 High lead Ball Screws

### Feature

It is important for a high lead Ball Screw to be with characteristics of high rigidity, low noise and thermal control. ABBA designs and treatments are taken for following:

1. High DN value
   - The DN value can be 130,000 in normal case. For some special cases, for example in a fixed ends case, the DN value can be as high as 140,000. Please contact our engineers for this special application.
2. High speed
   - ABBA high speed Ball Screws provide 100 m/min and even higher traverse speed for machine tools for high performance cutting.
3. High rigidity
   - Both the screw and  ball nut are surface hardened to a specific hard-ness and case depth to maintain high rigidity and durability.
   - Multiple thread starts are available to make more steel balls loaded in the ball nut for higher rigidity and durability.
4. Low noise
   - Special design of ball circulation tubes (patent pending) offer smooth ball circulation inside the ball nut. It also makes safe ball fast running into the tubes without damaging the tubes.
   - Accurate ball circle diameter (BCD) through whole threads for consistent drag torque and low noise.



Low noise circulation's nut

# 6.3.2 Axial Rigidity

Excessively weak rigidity of the screw's peripheral structure is one of the primary causes that result in lost motion. Therefore in order to achieve excellent positioning accuracy for the precision machines such as NC working machine, 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 from the formula below.

$$K = \frac{P}{e} \quad (kgf/\mu m)$$

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

e : Axial flexural displacement (mm)

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

$K_S$ : Axial rigidity of screw shaft (1)

$K_N$ : Axial rigidity of nut (2)

$K_B$ : Axial rigidity of bracing shaft (3)

$K_H$ : Axial rigidity of installation portions of nuts and bearings (4)

(1) Axial rigidity Ks and displacement $\delta_S$ of screw shaft

$$K_S = \frac{P}{\delta_S} \quad (kgf/\mu m)$$

P : Axial load ( kgf )

For places of Fixed - Fixed installation

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

For places other than Fixed - Fixed installation

$$\delta_{SS} = \frac{PL_O}{AE} \quad (mm)$$

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

$\delta_{SF}$ : Direction displacement at places of fixed-fixed installation

$\delta_{SS}$ : Direction 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 ($2.1\times10^4\ kgf/mm^2$)

L : Distance between installations (mm)

$L_O$ : Distance between load applying points (mm)

(2) Axial rigidity $K_N$ and displacement $\delta_N$ of nut

$$K_N = \frac{P}{\delta_S} \quad (kgf/\mu m)$$

(a) In case of single nut

$$\delta_{NS} = \frac{K}{\sin\beta}\left(\frac{Q^2}{d}\right)^{1/3} \times \frac{1}{\xi} \quad (\mu m)$$

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

$$n = \frac{D_O\pi m}{d} \quad (each)$$

Q : Load of one steel ball ( kgf )

n : Number of steel ball

k : Constant determined based on material, shape, dimensions

$k \fallingdotseq 5.7\times10^{-4}$

$\beta$ : Angle of contact ($45^\circ$)

P : Axial load ( kgf )

d : Steel ball diameter ( mm )

$\xi$ : Accuracy, internal structure coefficient

m : Effective number of balls

$D_O$ : Steel ball center diameter (mm)

$\ell$ : Lead (mm)

$\alpha$ : Lead angle

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

(b) In case of double nuts

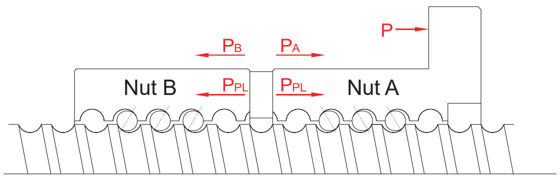



Fig. 6.3.2.1 Preloaded for the double nuts

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

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

$\delta_{NS}$ : Displacement of single nut ( mm )

$\delta_{NW}$ : Displacement of double nuts ( mm )

( Explanation of the rigidity of double nuts )

As shown in diagram Fig. 6.3.2.1 and 6.3.2.2, 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 X1, while nut B would move from X to X2. Then, based on the computing formula for displacement $\delta_{NS}$ of the single nut, we can obtain:

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

While displacements of nuts A & B are

$$\delta_A = aP_{PL}^{2/3}$$

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 that exerts 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 absorbed by nut A thus decreasing, so

When $\delta_B = 0$

$$aP_A^{2/3} - aP_{PL}^{2/3} = aP_{PL}^{2/3}$$

$$P_A^{2/3} = 2P_{PL}^{2/3}$$

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

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

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

thus it can also be judged from Fig. 6.3.2.3 that, when axial load is 3 times of preload laod, for a single nut with 1/2 displacement, the rigidity is 2 times as high.

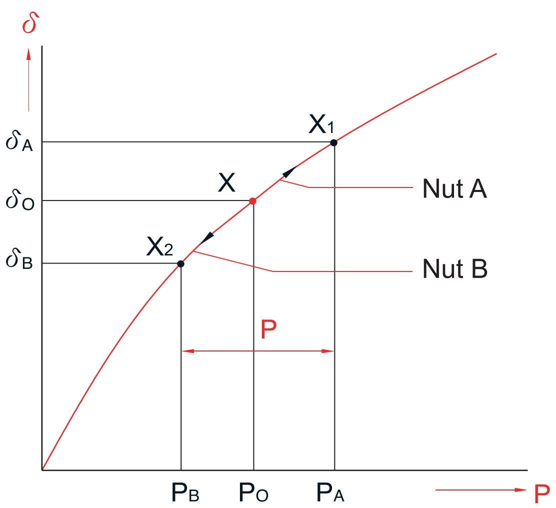



Fig. 6.3.2.2

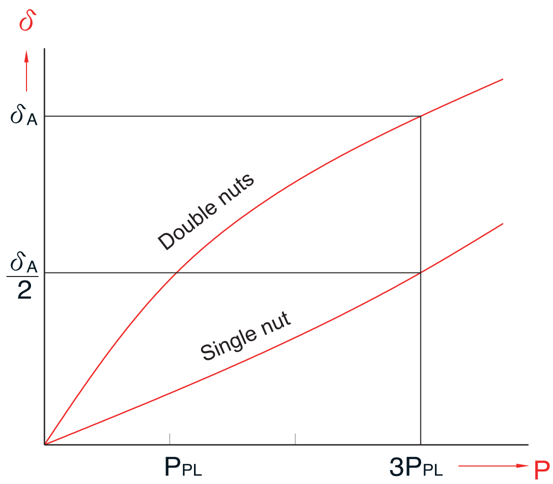



Fig. 6.3.2.3

(3) Axial rigidity $K_B$ and displacement $\delta_B$ of bracing shaft

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

The rigidity of the assembled diagonal thrust ball bearing that is used as the bracing bearing for the Ball Screw and is widely utilized in the field of precision machines can be found from the following formula.

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

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

Q : Load of one steel ball ( kgf )

$\beta$ : Angle of contact (45°)

d : Steel ball diameter ( mm )

$\ell_a$ : Effective distance of scroll

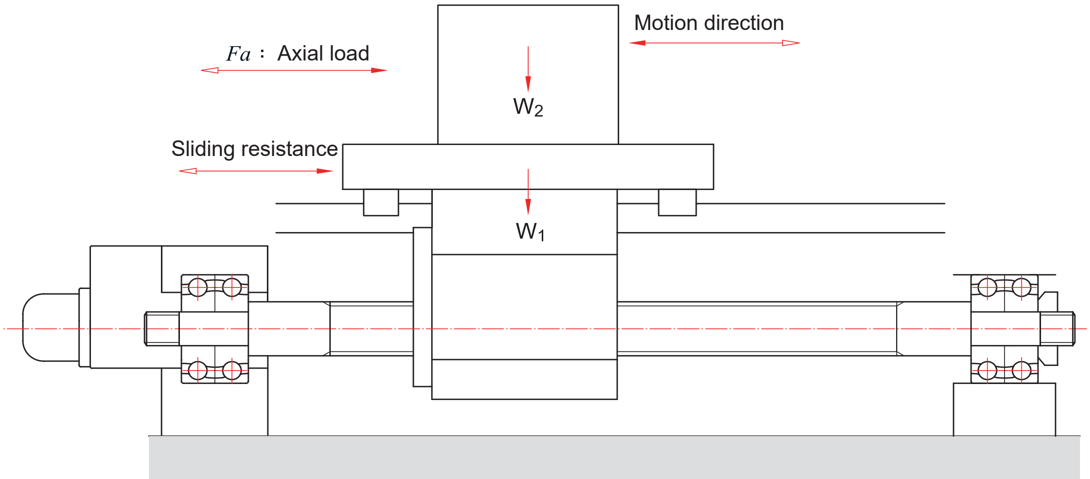
P : Axial load ( kgf )

n : Number of steel ball

(4) Axial rigidity $K_H$ and displacement $\delta_H$ of installation portions of nuts and bearings.
In early stage of machine development, special attentions should be paid to the requirement of high rigidity for the installation portion.

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

## 6.3.2.1 Horizontal reciprocating moving mechanism




Horizontal reciprocating moving mechanism

For reciprocal operation to move work horizontally ( back and forth ) in an conveyance system, the axial load (Fa) can be gotten using the following equations:

Acceleration ( leftward ) $Fa_1 = \mu \times mg + f + ma$

Constant speed ( leftward ) $Fa_2 = \mu \times mg + f$

Deceleration ( leftward ) $Fa_3 = \mu \times mg + f - ma$

Acceleration ( rightward ) $Fa_4 = -\mu \times mg - f - ma$

Constant speed ( rightward ) $Fa_5 = -\mu \times mg - f$

Deceleration ( rightward ) $Fa_6 = -\mu \times mg - f + ma$

Here

$a$ : Acceleration

$$a = \frac{V\text{max}}{t}$$

$V\text{max}$ : Rapid feed speed

$t$ : Acceleration time

$m$ : Total weight (table weight + work piece weight )

$\mu$ : Sliding surface friction coefficient

$f$ : Non-load resistance

## 6.3.2.2 Vertital reciprocating moving mechanism

For reciprocal operation to move work vertically ( back and forth ) in an conveyance system, the axial load (Fa) can be gotten using the following equations:

Acceleration ( upward ) $Fa_1 = mg + f + ma$

Constant speed ( upward ) $Fa_2 = mg + f$

Deceleration ( upward ) $Fa_3 = mg + f - ma$

Acceleration ( downward ) $Fa_4 = mg - f - ma$

Constant speed ( downward ) $Fa_5 = mg - f$

Deceleration ( downward ) $Fa_6 = mg - f + ma$

Here

$a$ : Acceleration

$$a = \frac{V\text{max}}{t_a}$$

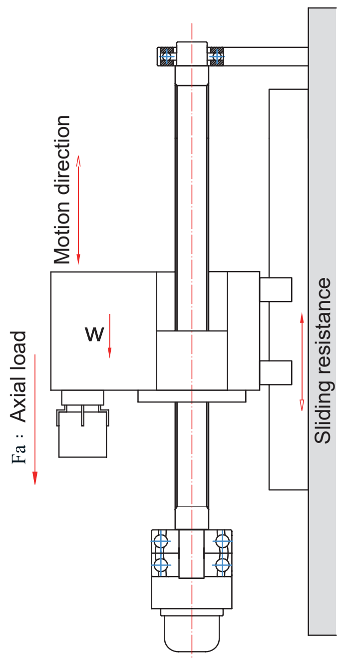
$V\text{max}$ : Rapid feed speed

$t_a$ : Acceleration time

$m$ : Total weight (table weight + work piece weight )

$\mu$ : Sliding surface friction coefficient

$f$ : Non-load resistance




Vertital reciprocating moving mechanism

# 6.4 Preload and effect

## 6.4.1 Ball Screw's preload and effect

In order to get high positioning accuracy, there are two ways to reach it. One is commonly known as to clear axial play to zero. The other one is to increase Ball Screw rigidity to reduce elastic deformation while taking axial load. Both two ways are done by preloading.

### 1 Methods of preloading

a. Double-nut method:

A spacer inserted between two nuts exerts a preload. There are two ways for it.

One is illustrated in Fig. 6.4.1.1 That is to use a spacer with thickness complies with required magnitude of preload. The spacer makes the gap between Nut A and B to be bigger, hence to produce a tension force on Nut A and B. it is called “extensive preload”.

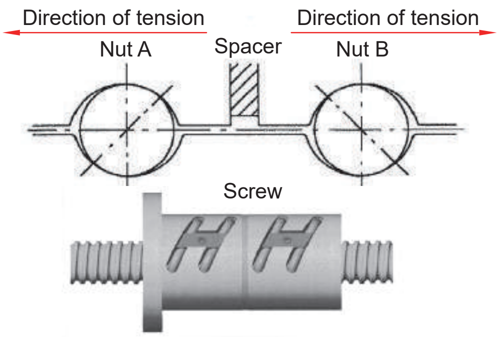



Fig. 6.4.1.1 Extensive preload

b. Single-nut method:

As that illustrated on Fig. 6.4.1.2 using oversize balls onto the space between Ball nut and screw to get required preload. The balls shall make four-point contact with grooves of Ball nut and screw.

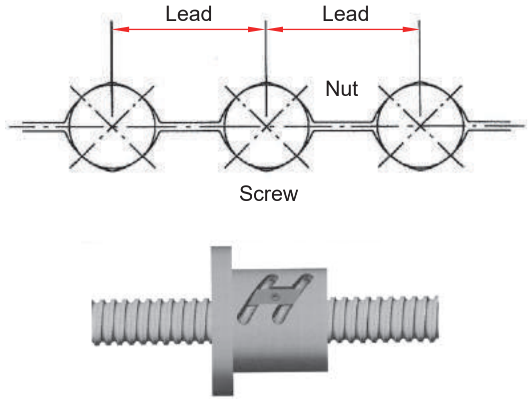



Fig. 6.4.1.2 Four point contact preload

### 2 Relation between preload force and elastic deformation

Fig. 6.4.1.3 Nuts A and B are assembled with preloading spacer. The preload forces on Nut A and B are $F_{ao}$,but with reversed direction. The elastic in Fig. 6.4.1.4 deformation on both Nuts are $\delta_{a0}$.

$$\delta_A = \delta_{a0} + \delta_{a1}$$
$$\delta_B = \delta_{a0} - \delta_{a1}$$

The load in nut A and nut B are:

$$F_A = F_{ao} + F_a - F_a' = F_a + F_p$$
$$F_B = F_{ao} - F_a' = F_p$$

**Note:** $F_A$ and $F_B$ have opposite directions

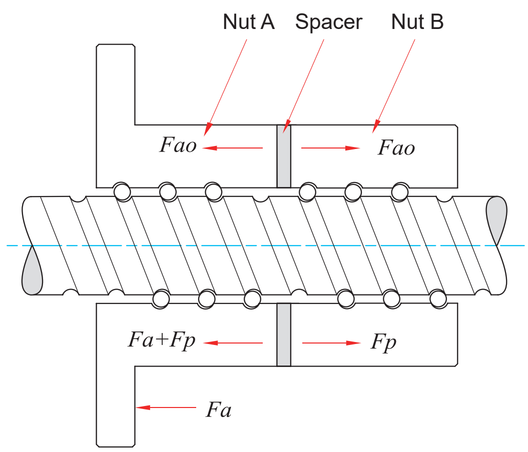



Fig. 6.4.1.3 Double-nut positioning preload

It means $Fa$ is offset with an amount $Fa'$ because of the deformation of Nut B decreases. As a result, the elastic deformation of Nut A is reduced. This effect shall be continued until the deformation of Nut B becomes zero, that is, until the elastic deformation $\delta_{a1}$ caused by the external axial force equals $\delta_{a0}$ , and the preload force applied to Nut B is completely released. The formula related the external axial force and elastic deformation is

$$\delta_{a0} = K \times Fao^{2/3} \text{ and } 2\delta_{a0} = K \times F_l^{2/3}$$

$$(F_l / Fao)^{2/3} = (2\delta_{a0} / \delta_{a0}) = 2$$

$$F_l = 2.8Fao \fallingdotseq 3Fao$$

Therefore, the preload amount of a Ball Screw is recommended to set as 1/3 of its axial load. Too much preload for a Ball Screw shall cause temperature raise and badly affect its life. However, taking the life and efficiency into consideration, the maximum preload amount of Ball Screw is commonly set to be 10% of its rated basic dynamic load.

Shown on Fig. 6.4.1.5 with the axial load to be three times as the preload, the elastic displacement for the non-preloaded ball nut is two times as that of the preloaded nut.

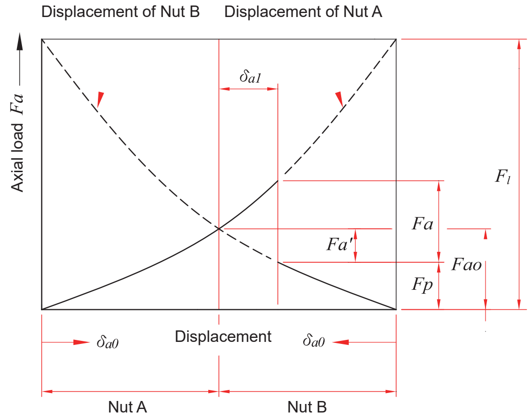



Fig. 6.4.1.4 Positioning preload diagram

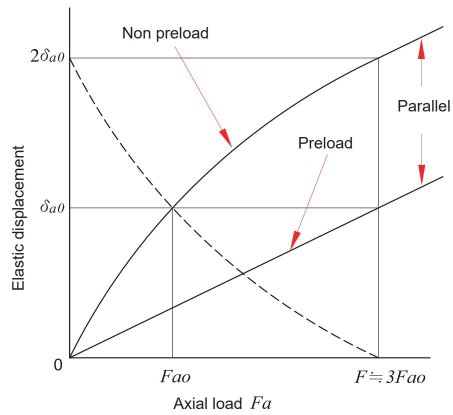



Fig. 6.4.1.5 Elastic displacement curve

## 6.4.2 Positioning accuracy

### 6.4.2.1 Causes of error in positioning accuracy

Lead error and rigidity of feed system are common causes of feed accuracy error. Other causes like thermal deformation and feed system assembly are also playing important roles in feed accuracy.

### 6.4.2.2 Considering thermal displacement

If the screw-shaft temperature increases during operation, the heat elongates the screw shaft, thereby reducing the positioning accuracy. Expansion and shrinkage of a screw shaft due to heat can be calculated using equation as below.

$$\Delta L_\theta = \rho \cdot \theta \cdot L$$

Here

$\Delta L_\theta$ : Thermal displacement ( μm )

$\rho$ : Thermal-expansion coefficient ( 12μm/m˚C )

$\theta$ : Screw-shaft temperature change ( ˚C )

$L$ : Ball screw length (mm)

That is to say, an increase in the screw shaft temperature of 1 expands the shaft by 12μm per meter. The higher the Ball Screw speed, the greater the heat generation. Thus, temperature increases reduce positioning accuracy. Where high accuracy. Where high accuracy is required, anti-temperature- elevation measures must be provided as follows:

**Note:** refer to Appendix (2) for examples of Ball Screws classes for different uses.

(1) To control temperature :
- Selecting appropriate preload
- Selecting correct and appropriate lubricant
- Selecting larger lead for Ball Screw and decrease the rotation speed

(2) Compulsory cooling:
- Ball Screw with hollow cooling
- Lubrication liquid or cooling air can be used to cool down external surface of Ball Screw.

(3) To keep off effect upon temperature raise:
- Set a negative cumulative lead target value for the Ball Screw
- Warm up the machine to stable machine's operating temperature
- Pretension by using on Ball Screw while installing onto the machine
- Positioning by closed loop

# 6.5 Life

## 6.5.1 Life of the Ball Screw

Even though the Ball Screw has been used with correct manner, it shall naturally be worn out and can no longer be used for a specified period. its life is defined by the period from starting use to ending use caused by nature fail.
a. Fatigue life - Time period for surface flaking off happened either on balls or on thread grooves.
b. Accuracy life - Time period for serious loosing of accuracy caused by wearing happened on thread groove surface, hence to make Ball Screw can no longer be used.

## 6.5.2 Fatigue life

The basic dynamic rate load ($C_a$) of the Ball Screw is used to calculate its fatigue life.

### 6.5.2.1 Basic dynamic rate load $Ca$

The basic dynamic rate load ($C_a$) is the revolution of $10^6$ that 90% of identical Ball Screw units in a group, when operated independently of one another under the same conditions, can achieve without developing flaking.

### 6.5.2.2 Fatigue life

1 **Calculation life:**

There are three ways to show fatigue life:
a. Total number of revolutions
b. Total operating time
c. Total travel

$$L = \left(\frac{Ca}{Fa \times f_w}\right)^3 \times 10^6$$

$$L_t = \frac{L}{60 \times n}$$

$$L_s = \frac{L \times l}{10^6}$$

Here

$L$ : Fatigue life ( total number of revolutions ) rev
$L_t$ : Fatigue life ( total operating time ) (hr)
$L_s$ : Fatigue life ( total travel ) (km)
$Ca$ : Basic dynamic rate load (kgf)
$Fa$ : Axial load (kgf)
$n$ : Rotation speed (rpm)
$l$ : Lead (mm)
$f_w$ : Load factor ( refer to Table 6.1 )

Load factor $f_w$

| Vibration and impact | Velocity $(V)$ | $f_w$ |
|---|---|---|
| Light | V<15 $(m/min)$ | 1.0~1.2 |
| Medium | 15<V<60 $(m/min)$ | 1.2~1.5 |
| Heavy | V>60 $(m/min)$ | 1.5~3.0 |

Too long or too short fatigue life are not suitable for Ball Screw selection. Using longer life make the Ball Screw selection. Using longer life make the Ball Screw's dimensions too large. It's an uneconomical result. Following table is a reference of Ball Screw's fatigue life.

Machine center ......................................20,000 hrs
Production machine..................................10,000 hrs
Automatic controller..................................15,000 hrs
Surveying instruments ...............................15,000 hrs

## 2 Mean load

When axial load change constantly. It is required to calculate the mean axial load ($F_m$) and the mean rotational speed ($N_m$) for fatigue life. Setting axial load ($Fa$) as Y-axis; rotational number ($n.t$) as X-axis. Getting three kind curves or lines.

a. Gradational variation curve (Fig. 6.5.2.1)

Mean load can be calculated by using equation :

$$F_m = \left( \frac{F_1^3 \cdot n_1 \cdot t_1 + F_2^3 \cdot n_2 \cdot t_2 + \cdots + F_n^3 \cdot n_n \cdot t_n}{n_1 \cdot t_1 + n_2 \cdot t_2 + \cdots + n_n \cdot t_n} \right)^{\frac{1}{3}}$$

Mean rotation speed can be calculated by using equation :

$$N_m = \frac{n_1 \cdot t_1 + n_2 \cdot t_2 + \cdots + n_n \cdot t_n}{t_1 + t_2 + \cdots + t_n}$$

| Axial load (kgf) | Rotation speed (rpm) | Time ratio (Sec) |
|---|---|---|
| $F_1$ | $n_1$ | $t_1$ |
| $F_2$ | $n_2$ | $t_2$ |
| ⋮ | ⋮ | ⋮ |
| $F_n$ | $n_n$ | $t_n$ |

b. Similar straight line (Fig. 6.5.2.2)

When mean load variation curve is like similar straight line Fig.6.5.2.2.
Mean rotational speed can be calculated by using equation.

$F_m = 1/3(F_{min} + F_{max})$

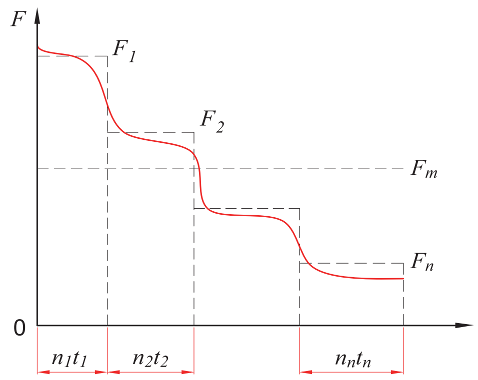



Fig. 6.5.2.1 Gradational variation curve's load

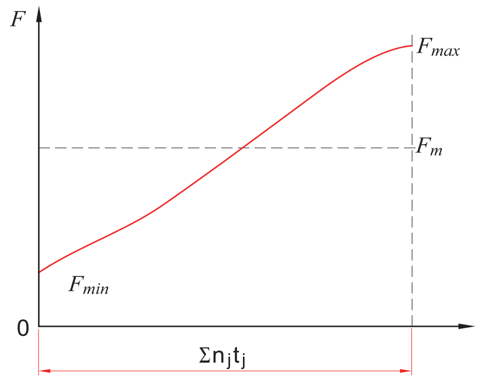



Fig. 6.5.2.2 Similar straight line's load

c. There are two cases when it display as Sine curve :

1. When mean load variation curve is shown as the diagram below ( Fig.6.5.2.3 )
   Mean rotational speed can be calculated by using equation.
   $F_m = 0.65F_{max}$
2. When mean load variation curve is shown as the diagram below ( Fig.6.5.2.4 )
   Mean rotational speed can be calculated by using equation.
   $F_m = 0.75F_{max}$

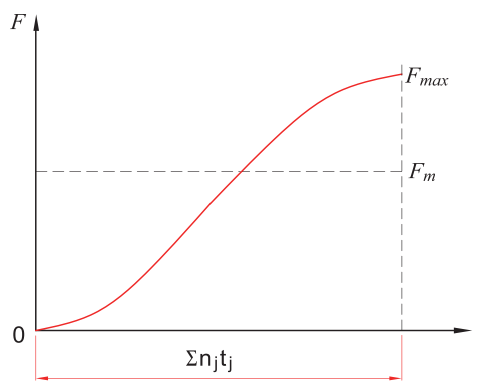



Fig. 6.5.2.3 Variation like Sine's curve load (1)

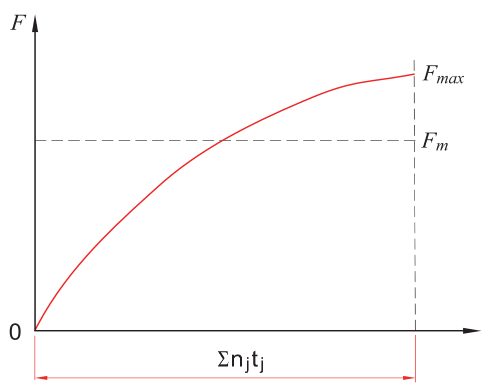



Fig. 6.5.2.4 Variation like Sine's curve load (2)

## 6.5.3 Material and Hardness

### Material and Hardness of ABBA Ball Screws

| Denomination | Material | Heat treating | Hardness (HRC) |
|---|---|---|---|
| Rolled | S55C | Induction hardening | 58~62 |
| Nut | SCM415H | Carburized hardening | 58~62 |

## 6.5.4 Lubrication

Lithium base lubricants are used for Ball Screw lubrication.
Their viscosity are 30~40 cst ( 40˚C ) and ISO grades of 32~100.
Selecting:

1. Low temperature application : Using the lower viscosity lubricant.
2. High temperature, high load and low speed application : Using the higher viscosity lubricant.

### Checking and supply interval of lubricant

The following table shows the general indicators of lubricant inspection and replenishment intervals.
Wipe off the old lubricant attached to the screw shaft during replenishment before replenishing

| Manner | Checking interval | Checking item | Supply or replacing interval |
|---|---|---|---|
| Automatic interval oil supply | Every week | Oil volume and purity | To supply on each check, its volume depends on oil tank capacity |
| Lubricating grease | Within 2-3 months after starting operation of machine | Foreign matter | Normally supply once a year as per the result of check |
| Oil bath | Everyday before operation of machine | Oil surface | To supply as per wasting condition |

## 6.5.5 Dustproof

Same as the rolling bearings, if there is the particles such as chips or water get into the Ball Screw, the wearing problem shall be deteriorated. In some serious cases, Ball Screw shall then be damaged. In order to prevent these problems from happening, there are wipers assembled at both ends of ball nut to scrape chips and dust. There is also the “O-Ring” at the wipers to seal the lubrication oil from leaking from ball nut.

# 6.5.6 Key points for Ball Screws selection and calculation

## Key points for Ball Screws selection

When Ball Screws are subjected to selection, it is a most fundamental rule that you must 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 are mutually related, any change to one of the 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

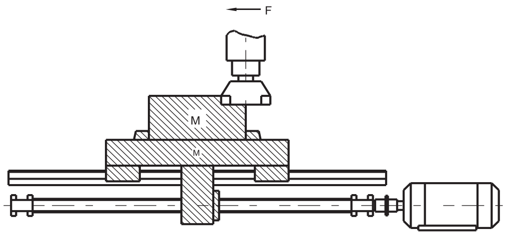
( b ) Mechanical conditions

| 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 is also important factors.

## Calculation for Ball Screws selection




### Design conditions

| | | | |
|---|---|---|---|
| 1. | Working table weight | 300 | Kg |
| 2. | Working object weight | 400 | Kg |
| 3. | Maximum stroke | 700 | mm |
| 4. | Fast feed speed | 10 | m/min |
| 5. | Minimal disassembly ability | 10 | μ m/stroke |
| 6. | Driving Motor DC Motor | (MAX 1000 $min^{-1}$) | |
| 7. | Guiding surface friction coefficeint | (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 = 12hr X 250 days X 10 years X 0.6 Running
=18000hr

( b ) Mechanical conditions

| Calculation Date / Difference Operations | Speed/rotations | Cutting resistance | Sliding resistance | Time used |
|---|---|---|---|---|
| Fast feed | 10m/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 Screws lead stroke** $\ell$ (mm)<br><br>$\ell = \dfrac{\text{Fast feed stroke (m/min)} \times 1000}{\text{Max. Rotating speed (min}^{-1})}$ (mm) | **2.Ball Screws lead stroke** $\ell$ (mm)<br><br>$\ell = \dfrac{10000}{1000} = 10$ (mm)<br><br>Minimal disassembly = $\dfrac{\text{10mm}}{\text{1000 stroke}}$ = 0.01 mm/stroke |
| **3.Computation of average load Pe ( kgf )**<br><br>$Pe = \left( \dfrac{P_1^3 n_1 t_1 + P_2^3 n_2 t_2 + \cdots + P_n^3 n_n t_n}{n_1 t_1 + n_2 t_2 + \cdots + n_n t_n} \right)^{1/3}$<br><br>$Pe = \dfrac{2Pmax + Pmin}{3}$<br><br>pe ≒ 0.65 Pmax<br>pe ≒ 0.75 Pmin | **3.Computation of average load Pe ( kgf )**<br><br>Pe =<br>$\left( \dfrac{70^3 \times 1000 \times 10 + 170^3 \times 600 \times 50 + 270^3 \times 200 \times 30 + 370^3 \times 100 \times 10}{1000 \times 10 + 600 \times 50 + 200 \times 30 + 100 \times 10} \right)^{1/3}$<br><br>$= \left( \dfrac{31.7 \times 10^{13}}{4.7 \times 10^{4}} \right)^{1/3}$<br><br>≒ 189 kgf |
| **4.Average number of rotation** $n_m$<br><br>$n_m = \dfrac{n_1 t_1 + n_2 t_2 + \cdots + n_n t_n}{100}$ | **4.Average number of rotation** $n_m$<br><br>$n_m = \dfrac{1000 \times 10 + 600 \times 50 + 200 \times 30 + 100 \times 10}{100}$<br><br>$= \dfrac{4.7 \times 10^4}{100}$<br><br>$= 470\ min^{-1}$ |
| **5.Calculation of required dynamic rated load Ca ( kgf )**<br><br>Ca = Pe • fs | **5.Calculation of required dynamic rated load Ca ( kgf )**<br><br>Ca = 189 × 5 = 945 (kgf) |
| **6.Calculation of required static rated load Coa ( kgf )**<br><br>Coa=Pmax • fs | **6.Calculation of required static rated load Coa ( kgf )**<br><br>Coa = 369 × 5 = 1845 (kgf) |
| **7.Selection of nut type**<br><br>Ca > 945 Coa > 1845<br>Select the nut types with basic dynamic rated load and basic static rated load as specified above. | **7.Selection of nut type**<br><br>Choose SFI 4010 on the catalogue<br>Ca = 3178 kgf<br>Coa = 9480 kgf |

| Key points for Ball Screws selection | Calculation for Ball Screws selection |
| --- | --- |

## 8. Calculation of life confirmation Lt (h)

$$L_t = \left(\frac{Ca}{Pe \cdot fw}\right)^3 \cdot \frac{1}{60n_m} \cdot 10^6$$

## 8. Calculation of life confirmation Lt (h)

$$L_t = \left(\frac{3178}{189 \cdot 2}\right)^3 \cdot \frac{1}{60 \cdot 470} \cdot 10^6$$

$$= 20479 \text{ (h)}$$

## 9. Determination of screw length

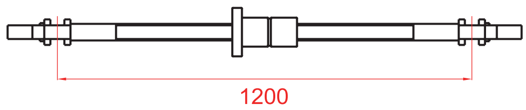
Screw length =
Maximal stroke + Nut length + 2 X reserved length at shaft end

## 9. Determination of screw length

Screw length = 700 + 93 + 2 x 81 = 874 mm

## 10. Mounting distance of screw length

## 10. Mounting distance of screw length (Fixed - Fixed)




## 11. Permissible axial load

## 11. Permissible axial load

Omitted because of Fixed - Fixed

## 12. Permissible revolution speed n and dm

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

dm = Shaft dia. X Maximal speed

## 12. Permissible revolution speed n and dm

$$n = \frac{21.9 \times 35.2 \times 10^7}{1200^2}$$

$$= 5353\text{min}^{-1} > n\text{max}$$

$$dm = 40 \times 1000$$

$$= 40000 < 50000$$

## 13. Countermeasure against thermal

$$\Delta L_\theta = \rho \cdot \theta \cdot L$$

Here

$\Delta L_\theta$ : Thermal displacement ( μm )

$\rho$ : Thermal-expansion coefficient ( 12μm/m˚C )

$\theta$ : Screw-shaft temperature change ( ˚C )

$L$ : Ball screw length (mm)

## 13. Countermeasure against thermal

It is estimated there would be a temperature rise of 2~5˚C with the Ball Screws of the general machinery, take temperature rise of 2˚C to computer the extension of Ball Screw.

$$\Delta L_\theta = \rho \cdot \theta \cdot L$$

$$= 12 \times 10^{-6} \times 2 \times 700 \text{ mm} \fallingdotseq 0.0168 \text{ mm}$$

$$F_P = \frac{EA\Delta L_\theta}{L}$$

$$= \frac{2.06 \times 10^4 \times \frac{\pi \times 35.2^2}{4} \times 0.0168}{700} \fallingdotseq 481 \text{kgf}$$

Deviation can be corrected by estimating the temperature rise per extension of 0.0168mm, and taking into consideration of the pre-tension of 481 kgf.

## Key points for Ball Screws selection

### 14. Rigidity review

(1) Axial rigidity Ks and displacement $\delta_S$ of screw shaft

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

P = Axial load ( kgf )

For places of Fixed - Fixed installation

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

(2) Axial rigidity $K_N$ and displacement $\delta_N$ of nut

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

In case of single nut

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

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

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

(3) Axial rigidity $K_B$ and displacement $\delta_B$ of Support bearing

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

### 15. Confirmation of the Ball Screw life

## Calculation for Ball Screws selection

### 14. Rigidity review

( 1 ) Rigidity

$$\delta_{SF} = \frac{PL}{4AE} = \frac{27 \times 1200}{4 \times \frac{\pi \times 35.2^2}{4} \times 2.06 \times 10^4}$$

$$= 0.00036 \text{ mm}$$

$$K_S = \frac{370}{0.00036} = 10.3 \times 10^5 \text{ kgf / mm}$$

( 2 ) Rigidity of steel ball and nut groove

$$n = \frac{41.8 \times \pi \times 2.5}{6.35} = 52$$

$$Q = \frac{370}{52 \sin 45^\circ} = 10$$

$$\delta_{NS} = \frac{0.00057}{\sin 45^\circ}\left(\frac{10^2}{6.35}\right)^{1/3} \times \frac{1}{0.7}$$

$$= 2.9 \times 10^{-3} \text{mm}$$

$$K_N = \frac{370}{2.9 \times 10^{-3}} = 1.28 \times 10^5 \text{kgf/mm}$$

( 3 ) Rigidity of brancing bearings
Where, nut rigidity 50 kgf/mm

$$\delta_B = \frac{370}{50 \times 2} = 3.7 \ \mu\text{m}$$

$$K_B = \frac{370}{0.0037} = 1 \times 10^5 \text{kgf/mm}$$

◎ $\delta_{TOTAL} = 0.36 + 2.9 + 3.7 = 6.96 \ \mu\text{m}$

### 15. Confirmation of the Ball Screw life

L = 20479(h) > 18000 (h)

# 6.6 Driving torque

## 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 torque $T_G$

$$T_G = J\alpha \quad (\text{kgf} \cdot \text{cm})$$

$$\alpha = \frac{2\pi n}{60\Delta t} \quad (\text{rad/s}^2)$$

- J : Moment of inertia (kgf • cm • s$^2$)
- $\alpha$ : Angular acceleration (rad/s$^2$)
- n : Revolutions (min$^{-1}$)
- $\Delta t$ : Starting time (sec)

### 2 Load torque $T_P$

$$T_P = \frac{P \cdot \ell}{2\pi\eta_1} \quad (\text{kgf} \cdot \text{cm})$$

$$P = F + \mu Mg$$

- P : Axial load (kgf)
- $\ell$ : lead (cm)
- $\eta_1$ : Positive efficiency
  - The efficiency when rotating motion is altered to linear motion
- F : Cutting force (kgf)
- $\mu$ : Friction coefficient
- M : Mass of moving object (kg)
- g : Acceleration of gravity (9.8 m/s$^2$)

$$T_P = \frac{P \cdot \ell \cdot \eta_2}{2\pi}$$

- $\eta_2$ : Reverse efficiency
  - The efficiency when linear motion returns to rotating motion

### 3 Preload torque $T_D$

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

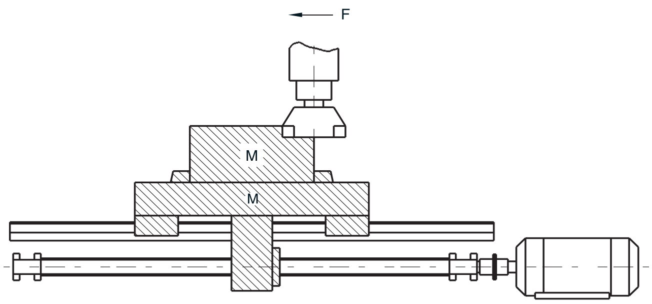
- K : Internal coefficient (0.05 is usually adopted)
- $P_{PL}$ : Preload (kgf)
- $\ell$ : Lead (cm)
- $\alpha$ : Lead angle

### 4 Friction torque $T_F$

$$T_F = T_B + T_O + T_J \quad (\text{kgf} \cdot \text{cm})$$

- $T_B$ : Friction torque of bracing shaft
- $T_O$ : Friction torque of free shaft
- $T_J$ : Friction torque motor shaft

The friciton 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 temperature rise.




Moment of inertia of load

【For reference】Moment of inertia of load

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

- $J_{BS}$ : 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

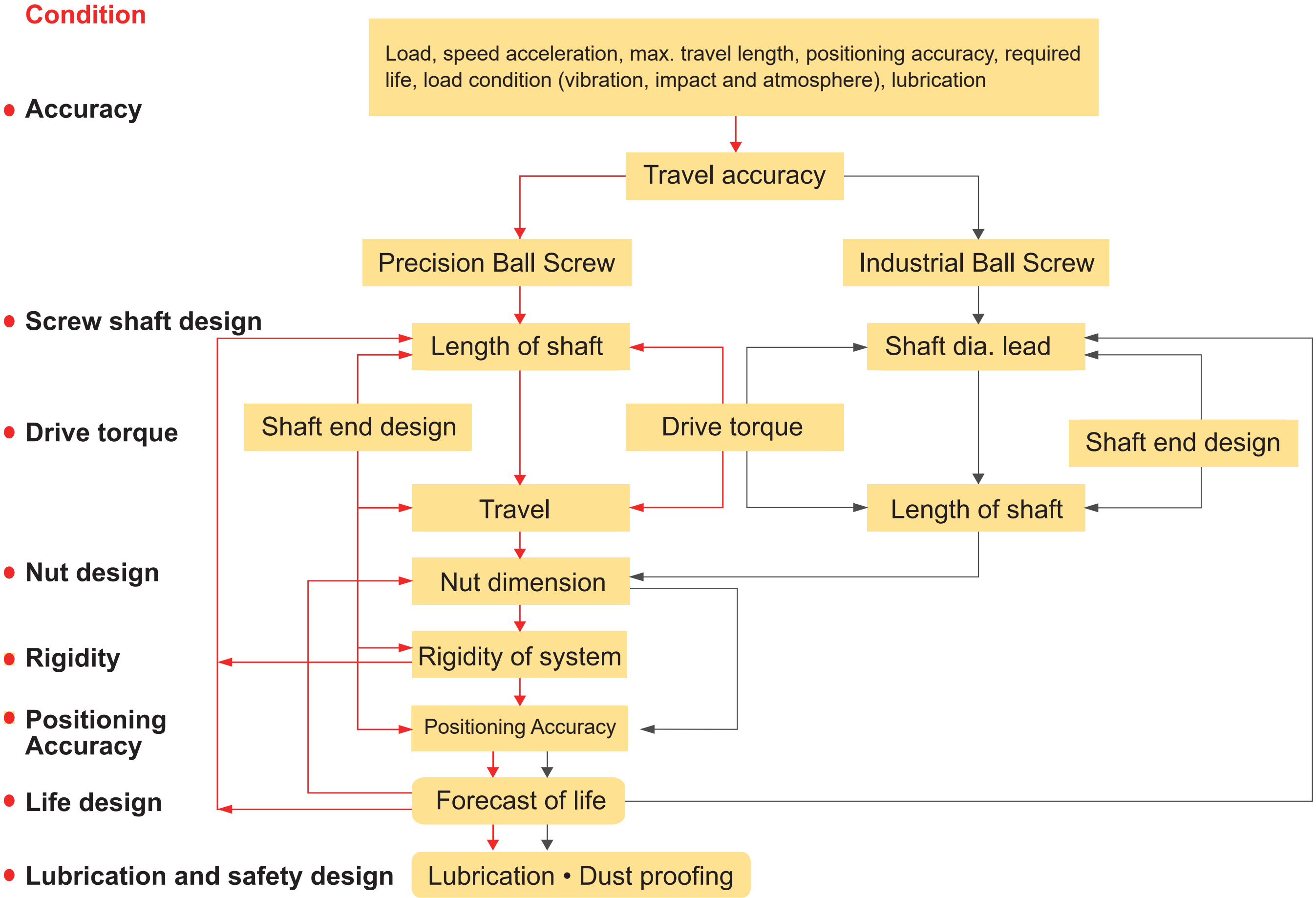
## Conversion formula for moment of inertia of load

| Moment of inertia converted from motor shaft \ Formula | J |
|---|---|
| Cylinder load | $\frac{\pi\rho LD^4}{32}$ |
| 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 • m$^2$ |
| Moment if inertia during deceleration | $J_M = \left(\frac{J\ell}{N_M}\right)^2 \cdot J\ell$ |

- $\rho$ : Density (kg / m$^3$) $\rho = 7.8 \times 10^3$
- L : Cylinder length (m)
- D : Cylinder diameter (m)
- M : Mass of linear motion part (kg)
- $V\ell$ : Velocity of linearly 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

# 6.7 Selecting correct type Ball Screw

## Condition




ABBA Ball Screw size list

| Dia. \ Lead | 1 | 2 | 2.5 | 3 | 4 | 5 | 5.08 | 6 | 10 | 12.7 | 16 | 20 | 25 | 32 | 40 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | ⦿ | | | | | | | | | | | | | | | |
| 8 | ⦿ | ⦿ | ⦿ | | | | | | | | | | | | | |
| 10 | | ⦿ | | ⦿ | ⦿ | | | | | | | | | | | |
| 12 | | ⦿ | | | ⦿ | ⦿ | | | ⦿ | ⦿ | | | | | | |
| 14 | | ⦿ | | | ⦿ | ⦿ | | | | | | | | | | |
| 15 | | | | | | | | | | | | ⦿ | | | | |
| 16 | | ⦿ | | | ⦿ | ⦿ | ⦿ | | ⦿ | | ⦿ | | | | | |
| 20 | | | | | | ⦿ | | | ⦿ | | | ⦿ | | | | |
| 25 | | | | | ⦿ | ⦿ | | | ⦿ | | | ⦿ | ⦿ | | | |
| 32 | | | | | | ⦿ | | ⦿ | ⦿ | | | ⦿ | | ⦿ | | |
| 40 | | | | | | ⦿ | | ⦿ | ⦿ | | | ⦿ | | | ⦿ | |
| 50 | | | | | | | | | ⦿ | | | ⦿ | | | | ⦿ |
| 63 | | | | | | | | | ⦿ | | | ⦿ | | | ⦿ | |
| 80 | | | | | | | | | ⦿ | | | ⦿ | | | | |

⦿ Rolled Ball Screw

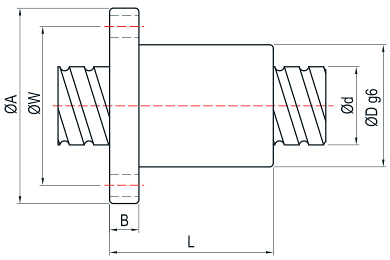
# 6.8 Ordering key of Ball Screw

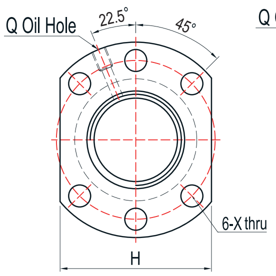
**2R25-25A2-2-FSED-2000-2500-0.05-R-P0**

- **Preload** : P0 With backlash  P1 Non-backlash
- **R:** Rolled
- **Accuracy grade** 0.05 : C7
  0.018 : C5
- **Screw Overall length**
- **Screw length**
- **Flange type** N: Non-cutting
  S: Single-cutting
  D: Double-cutting
- **Circulation type** H: Convex tube outer circulation
  U: European regulations DIN69051
  I : Inner loop
  E: High lead
  C: Low noise
- **Nut type** Y: Cylindrical keyway
  K: Miniature
  S: Single nut
  D: Double nut
- **Flange type** (F:With flange, R:Without flange, X:Special flange)
- **Number of nuts on a single screw**
- **Number of ball return caps per nut**
- **No. of Turn (circuits) or Turn x Row**
  T: 1 circuit
  A: 1.8 circuits
  B: 2.5 circuits
  C: 3.5 circuits
- **Lead**
- **Shaft dia.**
- **Direction of helix** R : Right / L : Left
- **Number of thread teeth** (single thread is not marked)

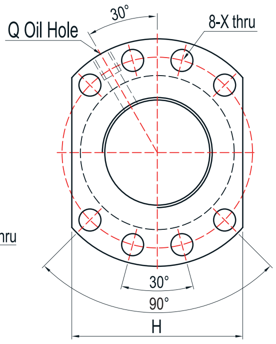
# 6.9 Dimension of Ball Screw

## 6.9.1 FSU (DIN69051)

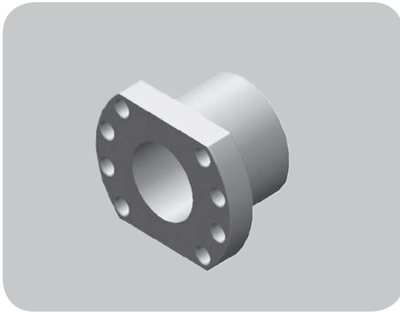



Type A




Type B

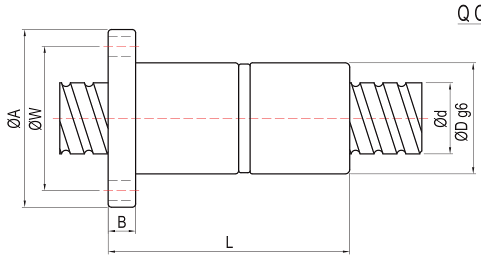


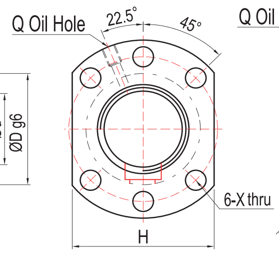
Unit : mm

| Model No. | Dimensions | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | I | Da | D | A | B | L | W | X | Type | H | Q | n | Ca(Kgf) | Coa(kgf) |
| 1204-4 | 12 | 4 | 2.381 | 24 | 40 | 10 | 40 | 32 | 4.5 | A | 30 | M6 | T4 | 816 | 1489 |
| 1604-4 | 16 | 4 | 2.381 | 28 | 48 | 10 | 45 | 38 | 5.5 | A | 40 | M6 | T4 | 939 | 2048 |
| ★ 1605-3 | 16 | 5 | 3.175 | 28 | 48 | 10 | 42 | 38 | 5.5 | A | 40 | M6 | T3 | 1063 | 1957 |
| ★ 1605-4 | 16 | 5 | 3.175 | 28 | 48 | 10 | 50 | 38 | 5.5 | A | 40 | M6 | T4 | 1361 | 2609 |
| 2005-3 | 20 | 5 | 3.175 | 36 | 58 | 10 | 47 | 47 | 6.6 | A | 44 | M6 | T3 | 1192 | 2542 |
| ★ 2005-4 | 20 | 5 | 3.175 | 36 | 58 | 10 | 53 | 47 | 6.6 | A | 44 | M6 | T4 | 1527 | 3390 |
| 2006-3 | 20 | 6 | 3.969 | 36 | 58 | 10 | 52 | 47 | 6.6 | A | 44 | M6 | T3 | 1589 | 3062 |
| 2010-3 | 20 | 10 | 3.969 | 36 | 58 | 10 | 68 | 47 | 6.6 | A | 44 | M6 | T3 | 1603 | 3122 |
| 2504-4 | 25 | 4 | 2.381 | 40 | 62 | 11 | 46 | 51 | 6.6 | A | 48 | M6 | T4 | 1173 | 3350 |
| 2505-3 | 25 | 5 | 3.175 | 40 | 62 | 10 | 47 | 51 | 6.6 | A | 48 | M6 | T3 | 1340 | 3268 |
| ★ 2505-4 | 25 | 5 | 3.175 | 40 | 62 | 10 | 53 | 51 | 6.6 | A | 48 | M6 | T4 | 1716 | 4357 |
| 2510-3 | 25 | 10 | 4.762 | 40 | 62 | 12 | 75 | 51 | 6.6 | A | 48 | M6 | T3 | 2260 | 4657 |
| 2510-4 | 25 | 10 | 4.762 | 40 | 62 | 12 | 85 | 51 | 6.6 | A | 48 | M6 | T4 | 2894 | 6210 |
| ★ 3205-4 | 32 | 5 | 3.175 | 50 | 80 | 12 | 53 | 65 | 9 | A | 62 | M6 | T4 | 1932 | 5705 |
| 3206-4 | 32 | 6 | 3.969 | 50 | 80 | 12 | 58 | 65 | 9 | A | 62 | M6 | T4 | 2592 | 6979 |
| 3210-3 | 32 | 10 | 6.35 | 50 | 80 | 16 | 77.5 | 65 | 9 | A | 62 | M6 | T3 | 3721 | 7924 |
| 3210-4 | 32 | 10 | 6.35 | 50 | 80 | 16 | 90 | 65 | 9 | A | 62 | M6 | T4 | 4765 | 10565 |
| ★ 4005-4 | 40 | 5 | 3.175 | 63 | 93 | 16 | 56 | 78 | 9 | B | 70 | M8 | T4 | 2147 | 7250 |
| 4006-4 | 40 | 6 | 3.969 | 63 | 93 | 14 | 60 | 78 | 9 | B | 70 | M6 | T4 | 2880 | 8862 |
| 4010-4 | 40 | 10 | 6.35 | 63 | 93 | 18 | 93 | 78 | 9 | B | 70 | M8 | T4 | 5331 | 13636 |
| 5006-4 | 50 | 6 | 3.969 | 75 | 110 | 15 | 62 | 93 | 11 | B | 85 | M8 | T4 | 3208 | 11324 |
| 5010-4 | 50 | 10 | 6.35 | 75 | 110 | 18 | 93 | 93 | 11 | B | 85 | M8 | T4 | 5986 | 17502 |
| 6310-4 | 63 | 10 | 6.35 | 90 | 125 | 18 | 98 | 108 | 11 | B | 95 | M8 | T4 | 6727 | 22820 |
| 6320-3 | 63 | 20 | 9.525 | 95 | 135 | 20 | 138 | 115 | 13.5 | B | 100 | M8 | T3 | 8931 | 24831 |
| 8010-4 | 80 | 10 | 6.35 | 105 | 145 | 20 | 98 | 125 | 13.5 | B | 110 | M8 | T4 | 7519 | 29386 |
| 8020-3 | 80 | 20 | 9.525 | 125 | 165 | 25 | 143 | 145 | 13.5 | B | 130 | M8 | T3 | 10076 | 32217 |

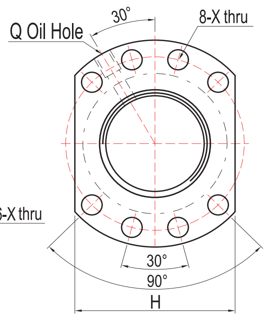
**Note:** with sign ★ can produce left helix

# 6.9.2 FDU (DIN69051)

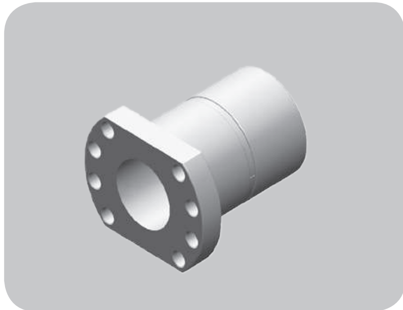



Type A




Type B

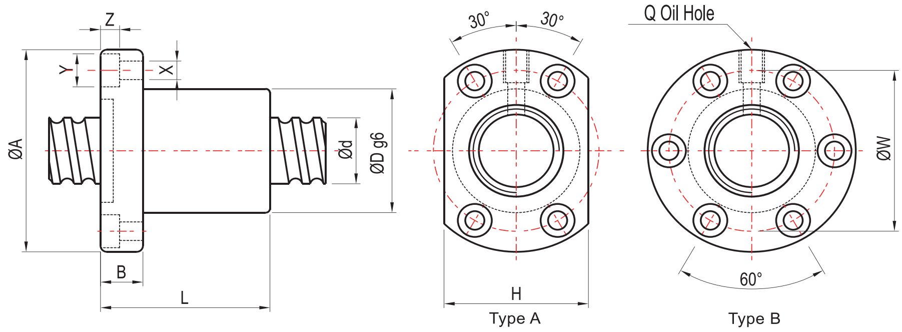


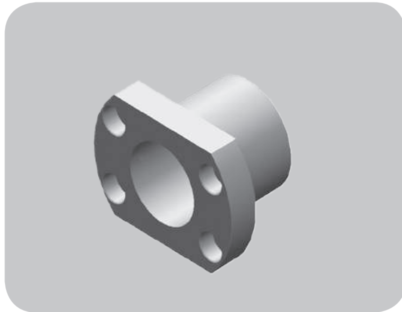
Unit : mm

| Model No. | Dimensions | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | I | Da | D | A | B | L | W | X | Type | H | Q | n | Ca(Kgf) | Coa(kgf) |
| ★ 1605-3 | 16 | 5 | 3.175 | 28 | 48 | 10 | 80 | 38 | 5.5 | A | 40 | M6 | T3 | 1063 | 1957 |
| ★ 2005-4 | 20 | 5 | 3.175 | 36 | 58 | 12 | 92 | 47 | 6.6 | A | 44 | M6 | T4 | 1527 | 3390 |
| ★ 2505-4 | 25 | 5 | 3.175 | 40 | 62 | 12 | 92 | 51 | 6.6 | A | 48 | M6 | T4 | 1716 | 4357 |
| 2510-4 | 25 | 10 | 4.762 | 40 | 62 | 12 | 153 | 51 | 6.6 | A | 48 | M6 | T4 | 2896 | 6210 |
| ★ 3205-4 | 32 | 5 | 3.175 | 50 | 80 | 12 | 92 | 65 | 9 | A | 62 | M6 | T4 | 1932 | 5705 |
| 3210-4 | 32 | 10 | 6.35 | 50 | 80 | 16 | 160 | 65 | 9 | A | 62 | M6 | T4 | 4765 | 10565 |
| 4005-4 | 40 | 5 | 3.175 | 63 | 93 | 15 | 96 | 78 | 9 | B | 70 | M8 | T4 | 2147 | 7250 |
| 4010-4 | 40 | 10 | 6.35 | 63 | 93 | 18 | 162 | 78 | 9 | B | 70 | M8 | T4 | 5331 | 13636 |
| 5010-4 | 50 | 10 | 6.35 | 75 | 110 | 16 | 162 | 93 | 11 | B | 85 | M8 | T4 | 5986 | 17502 |
| 6310-4 | 63 | 10 | 6.35 | 90 | 125 | 18 | 182 | 108 | 11 | B | 95 | M8 | T4 | 6727 | 22820 |
| 6320-3 | 63 | 20 | 9.525 | 95 | 135 | 20 | 253 | 115 | 13.5 | B | 100 | M8 | T3 | 8931 | 24831 |
| 8010-4 | 80 | 10 | 6.35 | 105 | 145 | 20 | 182 | 125 | 13.5 | B | 110 | M8 | T4 | 7519 | 29386 |
| 8020-3 | 80 | 20 | 9.525 | 125 | 165 | 25 | 253 | 145 | 13.5 | B | 130 | M8 | T3 | 10076 | 32217 |

**Note:** with sign ★ can produce left helix

## 6.9.3 FSI



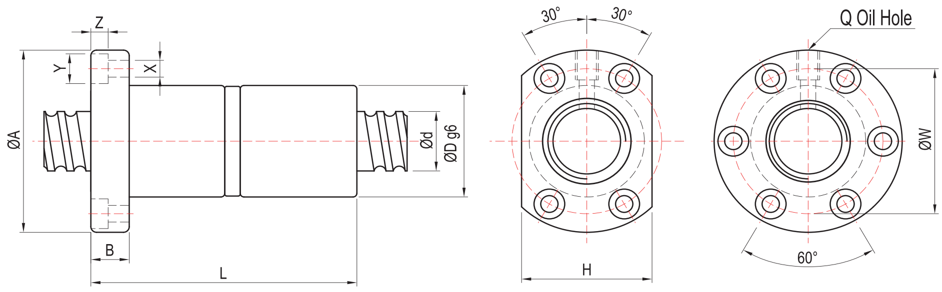



Unit : mm

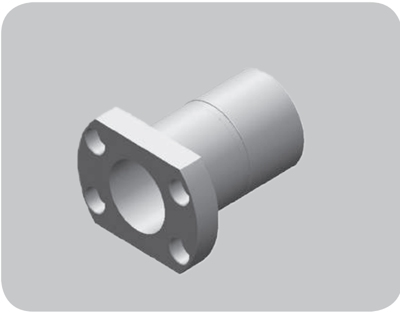
| Model No. | Dimensions | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | l | Da | D | A | B | L | W | X | Y | Z | Type | H | Q | n | Ca(Kgf) | Coa(kgf) |
| 1404-4 | 14 | 4 | 2.381 | 26 | 46 | 10 | 47 | 36 | 4.5 | 8 | 4.5 | A | 34 | M6 | T4 | 880 | 1769 |
| 1405-3 | 14 | 5 | 3.175 | 26 | 46 | 10 | 45 | 36 | 4.5 | 8 | 4.5 | A | 34 | M6 | T3 | 995 | 1686 |
| 1604-4 | 16 | 4 | 2.381 | 30 | 49 | 10 | 45 | 39 | 4.5 | 8 | 4.5 | A | 34 | M6 | T4 | 939 | 2048 |
| ★ 1605-3 | 16 | 5 | 3.175 | 30 | 49 | 10 | 42 | 39 | 4.5 | 8 | 4.5 | A | 34 | M6 | T3 | 1063 | 1957 |
| ★ 1605-4 | 16 | 5 | 3.175 | 30 | 49 | 10 | 50 | 39 | 4.5 | 8 | 4.5 | A | 34 | M6 | T4 | 1361 | 2609 |
| 1610-3 | 16 | 10 | 3.175 | 34 | 58 | 10 | 65 | 45 | 5.5 | 9.5 | 5.5 | A | 36 | M6 | T3 | 1490 | 3207 |
| ★ 2005-4 | 20 | 5 | 3.175 | 34 | 57 | 12 | 53 | 45 | 5.5 | 9.5 | 5.5 | A | 40 | M6 | T4 | 1527 | 3390 |
| 2010-3 | 20 | 10 | 3.969 | 46 | 74 | 13 | 54 | 59 | 6.6 | 11 | 5.5 | A | 46 | M6 | T3 | 1648 | 3554 |
| 2504-4 | 25 | 4 | 2.381 | 40 | 63 | 11 | 46 | 51 | 5.5 | 9.5 | 5.5 | A | 46 | M6 | T4 | 1173 | 3350 |
| ★ 2505-4 | 25 | 5 | 3.175 | 40 | 63 | 12 | 53 | 51 | 5.5 | 9.5 | 5.5 | A | 46 | M8 | T4 | 1716 | 4357 |
| 2510-4 | 25 | 10 | 4.762 | 46 | 72 | 12 | 85 | 58 | 6.5 | 11 | 6.5 | A | 52 | M6 | T4 | 2894 | 6210 |
| ★ 3205-4 | 32 | 5 | 3.175 | 46 | 72 | 12 | 53 | 58 | 6.5 | 11 | 6.5 | A | 52 | M8 | T4 | 1932 | 5705 |
| 3206-4 | 32 | 6 | 3.969 | 62 | 89 | 12 | 63 | 75 | 6.5 | 11 | 6.5 | B | - | M8 | T4 | 2592 | 6897 |
| 3210-4 | 32 | 10 | 6.35 | 54 | 88 | 16 | 90 | 70 | 9 | 14 | 8.5 | A | 62 | M8 | T4 | 4765 | 10565 |
| ★ 4005-4 | 40 | 5 | 3.175 | 56 | 90 | 16 | 56 | 72 | 9 | 14 | 8.5 | A | 64 | M8 | T4 | 2147 | 7250 |
| 4010-4 | 40 | 10 | 6.35 | 62 | 104 | 18 | 93 | 82 | 11 | 17.5 | 11 | A | 70 | M8 | T4 | 5331 | 13636 |
| 5010-4 | 50 | 10 | 6.35 | 72 | 114 | 18 | 93 | 92 | 11 | 17.5 | 11 | A | 82 | M8 | T4 | 5986 | 17502 |
| 6310-4 | 63 | 10 | 6.35 | 85 | 131 | 22 | 100 | 107 | 14 | 20 | 13 | B | - | M8 | T4 | 6727 | 22820 |
| 6320-3 | 63 | 20 | 9.525 | 95 | 153 | 23 | 130 | 123 | 18 | 26 | 17.5 | B | - | M8 | T3 | 8931 | 24831 |
| 8010-4 | 80 | 10 | 6.35 | 105 | 150 | 22 | 92 | 127 | 14 | 20 | 13 | B | - | M8 | T4 | 7519 | 29386 |
| 8020-3 | 80 | 20 | 9.525 | 115 | 173 | 23 | 130 | 143 | 18 | 26 | 17.5 | B | - | M8 | T3 | 10076 | 32217 |

**Note:** with sign ★ can produce left helix

# 6.9.4 FDI




Type A    Type B

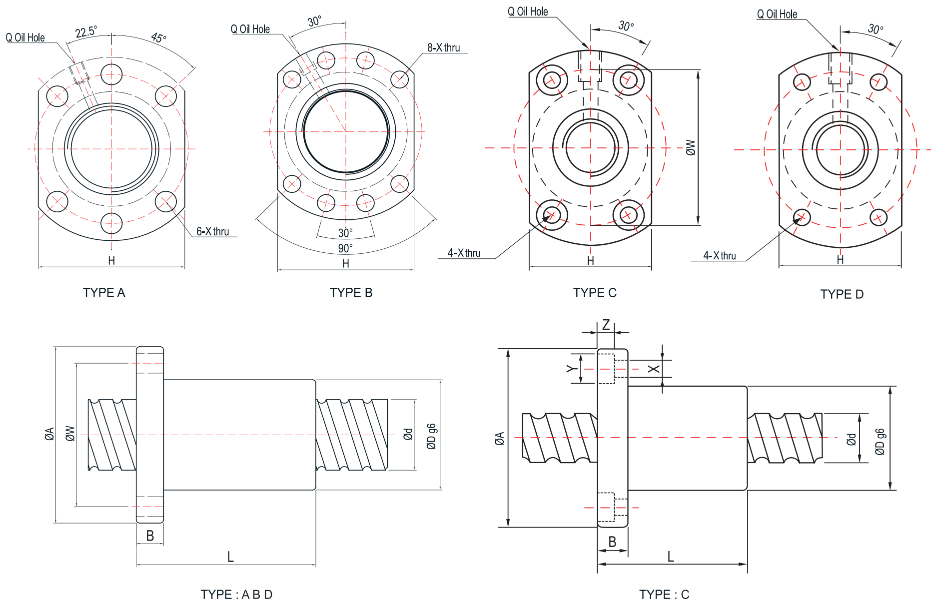


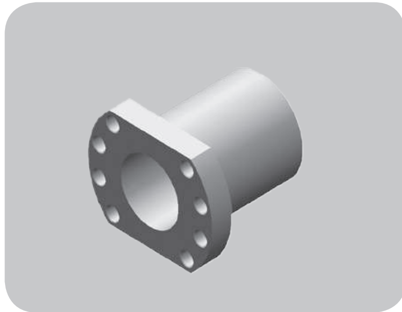
Unit : mm

| Model No. | Dimensions | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | l | Da | D | A | B | L | W | X | Y | Z | Type | H | Q | n | Ca(Kgf) | Coa(kgf) |
| ★ 1605-3 | 16 | 5 | 3.175 | 30 | 49 | 10 | 80 | 39 | 4.5 | 8 | 4.5 | A | 34 | M6 | T3 | 1063 | 1957 |
| ★ 2005-4 | 20 | 5 | 3.175 | 34 | 57 | 12 | 92 | 45 | 5.5 | 9.5 | 5.5 | A | 40 | M6 | T4 | 1527 | 3390 |
| ★ 2504-4 | 25 | 4 | 2.381 | 40 | 63 | 11 | 80 | 51 | 5.5 | 9.5 | 5.5 | A | 46 | M6 | T4 | 1173 | 3350 |
| ★ 2505-4 | 25 | 5 | 3.175 | 40 | 63 | 12 | 92 | 51 | 5.5 | 9.5 | 5.5 | A | 46 | M8 | T4 | 1716 | 4357 |
| 2510-4 | 25 | 10 | 4.762 | 46 | 72 | 12 | 156 | 58 | 6.5 | 11 | 6.5 | A | 52 | M6 | T4 | 2894 | 6210 |
| ★ 3205-4 | 32 | 5 | 3.175 | 46 | 72 | 12 | 92 | 58 | 6.5 | 11 | 6.5 | A | 52 | M8 | T4 | 1932 | 5705 |
| 3210-4 | 32 | 10 | 6.35 | 54 | 88 | 16 | 160 | 70 | 9 | 14 | 8.5 | A | 62 | M8 | T4 | 4765 | 10565 |
| ★ 4005-4 | 40 | 5 | 3.175 | 56 | 90 | 16 | 96 | 72 | 9 | 14 | 8.5 | A | 64 | M8 | T4 | 2147 | 7250 |
| 4010-4 | 40 | 10 | 6.35 | 62 | 104 | 18 | 162 | 82 | 11 | 17.5 | 11 | A | 70 | M8 | T4 | 5331 | 13636 |
| 5010-4 | 50 | 10 | 6.35 | 72 | 114 | 18 | 162 | 92 | 11 | 17.5 | 11 | A | 82 | M8 | T4 | 5986 | 17502 |
| 6310-4 | 63 | 10 | 6.35 | 85 | 131 | 22 | 182 | 107 | 14 | 20 | 13 | B | - | M8 | T4 | 6727 | 22820 |
| 6320-3 | 63 | 20 | 9.525 | 95 | 153 | 23 | 253 | 123 | 18 | 26 | 17.5 | B | - | M8 | T3 | 8931 | 24831 |
| 8010-4 | 80 | 10 | 6.35 | 105 | 150 | 22 | 182 | 127 | 14 | 20 | 13 | B | - | M8 | T4 | 7519 | 29386 |
| 8020-3 | 80 | 20 | 9.525 | 115 | 173 | 23 | 253 | 143 | 18 | 26 | 17.5 | B | - | M8 | T3 | 10076 | 32217 |

**Note:** with sign ★ can produce left helix

# 6.9.5 FSC



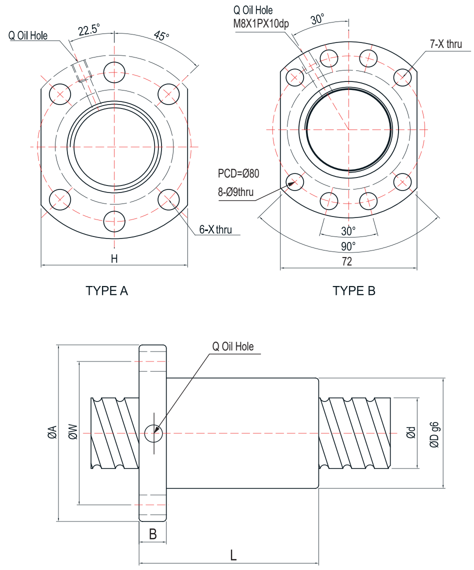



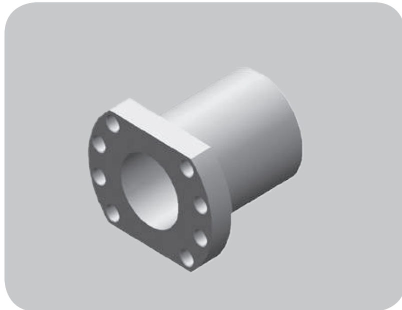
Unit : mm

| Model No. | Dimensions | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | l | Da | D | A | B | L | W | X | Y | Z | Type | H | Q | n | Ca(Kgf) | Coa(kgf) |
| 1205-3 | 12 | 5 | 2 | 24 | 40 | 8 | 30 | 32 | 3.6 | - | - | D | 25 | - | T3 | 513 | 1051 |
| 1210-2 | 12 | 10 | 2 | 30 | 50 | 10 | 40 | 40 | 4.5 | 8 | 4.5 | C | 32 | M6 | T2 | 347 | 657 |
| 1520-2 | 15 | 20 | 3.175 | 34 | 55 | 12 | 57 | 45 | 6 | - | - | D | 34 | M6 | T2 | 729 | 1353 |
| 1610-3 | 16 | 10 | 3.175 | 28 | 48 | 12 | 43 | 38 | 5.5 | - | - | A | 40 | M6 | T3 | 1097 | 2245 |
| 1616-4 | 16 | 16 | 3.175 | 28 | 48 | 12 | 61 | 38 | 5.5 | - | - | A | 40 | M6 | T4 | 1361 | 2886 |
| 2010-3 | 20 | 10 | 3.969 | 46 | 74 | 13 | 54 | 59 | 6.6 | 11 | 5.5 | C | 46 | M6 | T3 | 1648 | 3554 |
| 2525-4 | 25 | 25 | 3.969 | 47 | 74 | 12 | 67 | 60 | 6.6 | - | - | A | 56 | M6 | T4 | 2236 | 5590 |
| 3220-3 | 32 | 20 | 3.969 | 50 | 80 | 13 | 78 | 65 | 9 | - | - | A | 62 | M6 | T3 | 2013 | 5522 |
| 3232-4 | 32 | 32 | 4.762 | 56 | 86 | 16 | 82 | 71 | 9 | - | - | A | 65 | M6 | T4 | 3197 | 8612 |
| 4020-3 | 40 | 20 | 5.556 | 63 | 93 | 15 | 83 | 78 | 9 | - | - | B | 70 | M8 | T3 | 3530 | 9793 |
| 4040-4 | 40 | 40 | 6.35 | 65 | 95 | 18 | 100 | 80 | 9 | - | - | B | 72 | M8 | T4 | 5225 | 14404 |
| 5020-5 | 50 | 20 | 6.35 | 75 | 110 | 18 | 121 | 93 | 11 | - | - | B | 85 | M8 | T5 | 7401 | 23822 |
| 6310-6 | 63 | 10 | 6.35 | 90 | 135 | 20 | 94 | 108 | 13.5 | - | - | B | 100 | M8 | T6 | 8170 | 31750 |

**Note:** Steel balls 3.5mm, please order 3.5mm shaft to meet

# 6.9.6 FSS

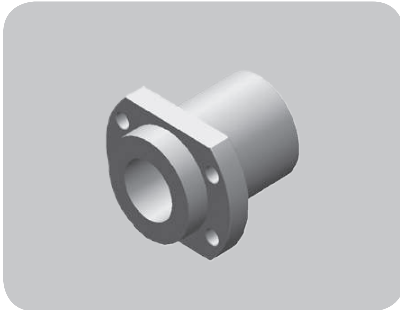


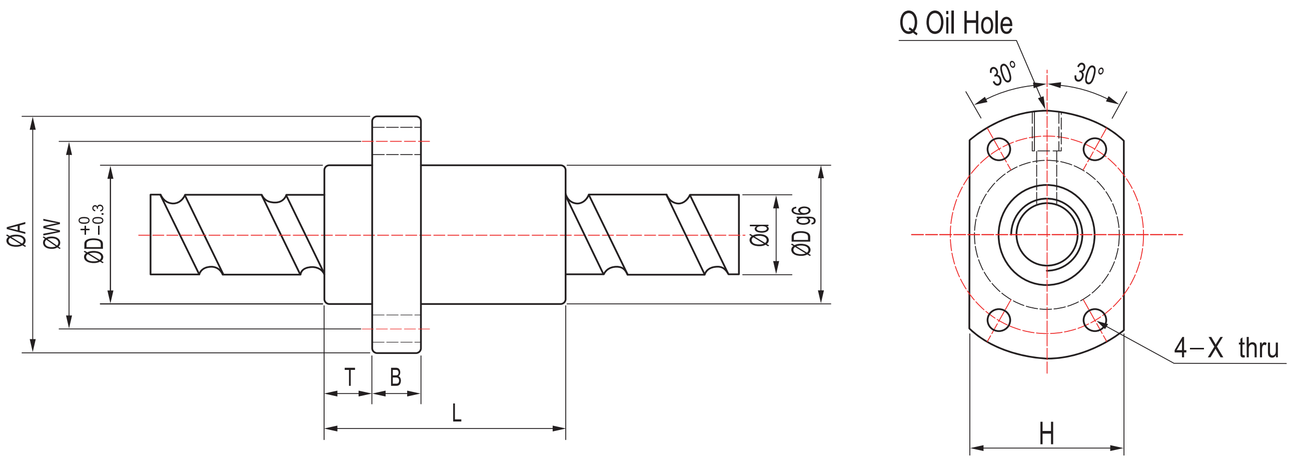



Unit : mm

| Model No. | Dimensions | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | I | Da | D | A | B | L | W | X | Type | H | Q | n | Ca(Kgf) | Coa(kgf) |
| 1205-2.8 | 12 | 5 | 2 | 24 | 40 | 8 | 30 | 32 | 4.5 | A | 30 | - | B1 | 513 | 1051 |
| 1210-1.8 | 12 | 10 | 2 | 24 | 40 | 8 | 34 | 32 | 4.5 | A | 30 | - | A1 | 347 | 657 |
| 1605-3.8 | 15 | 5 | 2.778 | 28 | 48 | 10 | 36 | 38 | 5.5 | A | 40 | M6 | C1 | 1159 | 2514 |
| 1610-2.8 | 15 | 10 | 2.778 | 28 | 48 | 10 | 46 | 38 | 5.5 | A | 40 | M6 | B1 | 891 | 1852 |
| 1616-1.8 | 15 | 16 | 2.778 | 28 | 48 | 10 | 45 | 38 | 5.5 | A | 40 | M6 | A1 | 609 | 1191 |
| 1520-1.8 | 15 | 20 | 2.778 | 28 | 48 | 10 | 54 | 38 | 5.5 | A | 40 | M6 | A1 | 609 | 1191 |
| 2005-3.8 | 20 | 5 | 3.175 | 36 | 58 | 10 | 36 | 47 | 6.6 | A | 44 | M6 | C1 | 1584 | 3867 |
| 2010-3.8 | 20 | 10 | 3.175 | 36 | 58 | 10 | 56 | 47 | 6.6 | A | 44 | M6 | C1 | 1584 | 3867 |
| 2020-3.6 | 20 | 20 | 3.175 | 36 | 58 | 10 | 55 | 47 | 6.6 | A | 44 | M6 | A2 | 1497 | 3581 |
| 2510-3.8 | 25 | 10 | 3.5 | 40 | 62 | 10 | 64 | 51 | 6.6 | A | 48 | M6 | C1 | 1978 | 5157 |
| 2525-1.8 | 25 | 25 | 3.175 | 40 | 62 | 10 | 65 | 51 | 6.6 | A | 48 | M6 | A1 | 920 | 2266 |
| 3232-3.6 | 32 | 32 | 4.762 | 50 | 80 | 16 | 82 | 65 | 9 | A | 62 | M6 | A2 | 3197 | 8612 |
| 4040-3.6 | 40 | 40 | 6.35 | 63 | 93 | 18 | 100 | 78 | 9 | B | 70 | M8 | A2 | 5225 | 14404 |

# 6.9.7 FSE



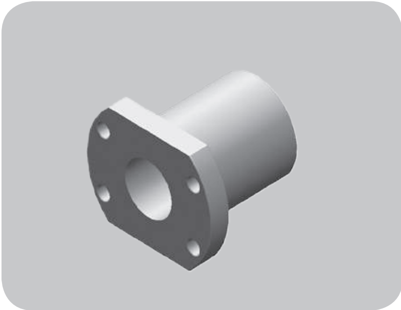


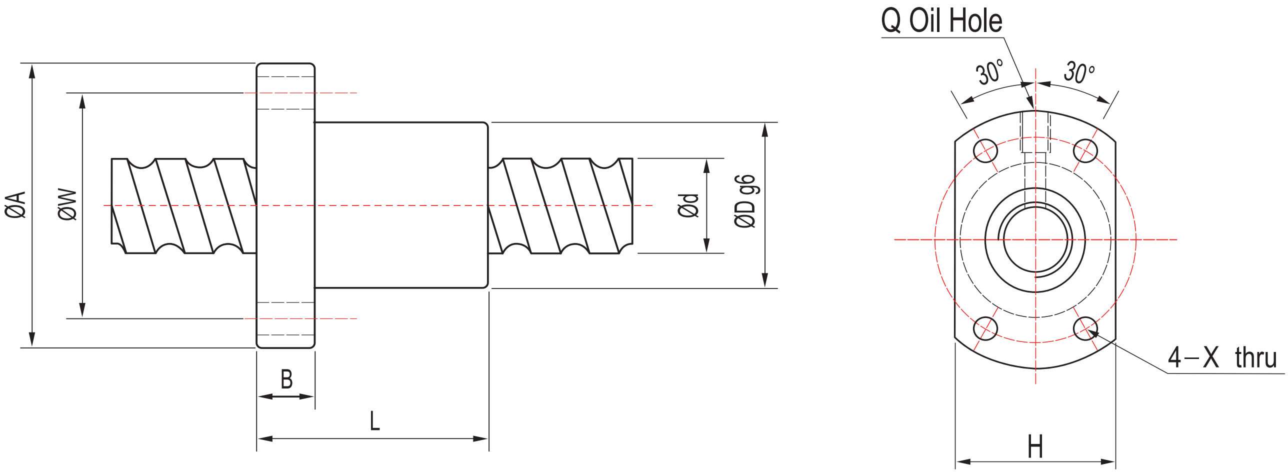

Unit : mm

| Model No. | Dimensions | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | I | Da | D | A | B | T | L | W | X | H | Q | n | Ca(Kgf) | Coa(kgf) |
| 1616-3.6 | 16 | 16 | 3.175 | 32 | 53 | 10 | 10.5 | 48 | 42 | 4.5 | 38 | M6 | A2 | 1361 | 2886 |
| ★ 2020-3.6 | 20 | 20 | 3.175 | 39 | 62 | 10 | 10.8 | 55 | 50 | 5.5 | 46 | M6 | A2 | 1497 | 3581 |
| 2520-3.6 | 25 | 20 | 3.5 | 47 | 74 | 12 | 11 | 65 | 60 | 6.6 | 49 | M6 | A2 | 1888 | 4885 |
| 2525-3.6 | 25 | 25 | 3.969 | 47 | 74 | 12 | 11.2 | 67 | 60 | 6.6 | 56 | M6 | A2 | 2236 | 5590 |
| 3232-3.6 | 32 | 32 | 4.762 | 58 | 92 | 15 | 14 | 82 | 74 | 9 | 68 | M6 | A2 | 3197 | 8612 |
| 4040-3.6 | 40 | 40 | 6.35 | 73 | 114 | 17 | 17 | 100 | 93 | 11 | 84 | M6 | A2 | 5225 | 14404 |
| 5050-3.6 | 50 | 50 | 7.938 | 90 | 135 | 20 | 21.5 | 125 | 112 | 14 | 92 | M6 | A2 | 7838 | 22704 |

**Note:** with sign ★ can produce left helix

# 6.9.8 FSB

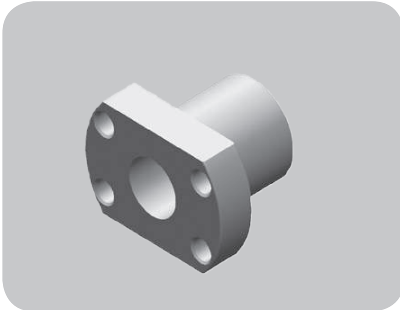


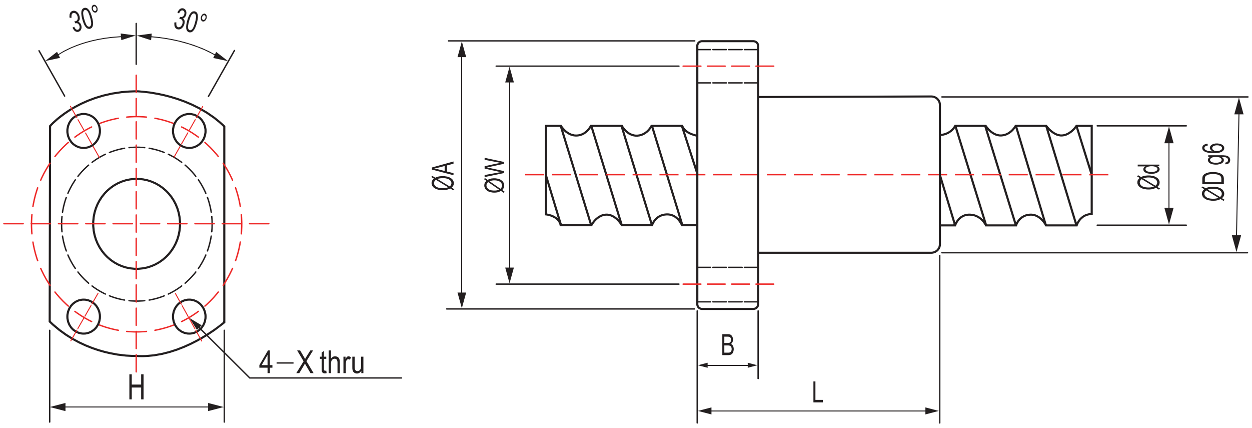



Unit : mm

| Model No. | Dimensions | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | l | Da | D | A | B | L | W | X | H | Q | n | Ca(Kgf) | Coa(kgf) |
| 1404-3 | 14 | 4 | 2.381 | 31 | 50 | 10 | 40 | 40 | 4.5 | 37 | M6 | T3 | 687 | 1327 |
| 1405-3 | 14 | 5 | 3.175 | 32 | 50 | 10 | 45 | 40 | 4.5 | 38 | M6 | T3 | 995 | 1686 |
| 1605-3 | 16 | 5 | 3.175 | 34 | 54 | 10 | 42 | 44 | 4.5 | 40 | M6 | T3 | 1063 | 1957 |
| 2005-3 | 20 | 5 | 3.175 | 40 | 60 | 10 | 47 | 50 | 4.5 | 46 | M6 | T3 | 1192 | 2542 |
| 2505-3 | 25 | 5 | 3.175 | 43 | 67 | 10 | 47 | 55 | 5.5 | 50 | M6 | T3 | 1340 | 3268 |
| 2510-3 | 25 | 10 | 4.762 | 60 | 96 | 15 | 75 | 78 | 9 | 72 | M6 | T3 | 2260 | 4257 |
| 2510-4 | 25 | 10 | 4.762 | 60 | 96 | 15 | 97 | 78 | 9 | 72 | M6 | T4 | 2894 | 6210 |
| 3210-3 | 32 | 10 | 6.35 | 67 | 103 | 15 | 78 | 85 | 9 | 78 | M6 | T3 | 3721 | 7924 |
| 3210-4 | 32 | 10 | 6.35 | 67 | 103 | 15 | 97 | 85 | 9 | 78 | M6 | T4 | 4765 | 10565 |
| 4010-4 | 40 | 10 | 6.35 | 76 | 116 | 17 | 100 | 96 | 11 | 88 | M6 | T4 | 5331 | 13636 |

## 6.9.9 FSK

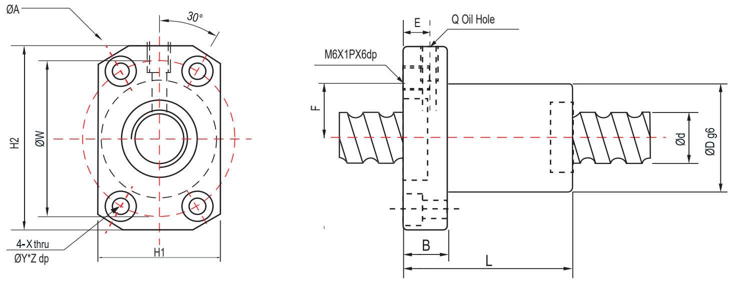


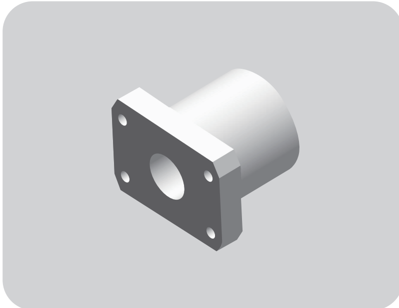



Unit : mm

| Model No. | Dimensions | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | l | Da | D | A | B | L | W | X | H | n | Ca(Kgf) | Coa(kgf) |
| 0601-3 | 6 | 1 | 0.8 | 12 | 24 | 3.5 | 18 | 18 | 3.4 | 16 | T3 | 111 | 201 |
| 0801-3 | 8 | 1 | 0.8 | 14 | 27 | 4 | 20 | 21 | 3.4 | 18 | T3 | 126 | 272 |
| 0802-3 | 8 | 2 | 1.2 | 16 | 29 | 4 | 26 | 23 | 3.4 | 20 | T3 | 215 | 398 |
| 0825-3 | 8 | 2.5 | 1.2 | 16 | 29 | 4 | 26 | 23 | 3.4 | 20 | T3 | 215 | 397 |
| 1002-3 | 10 | 2 | 1.2 | 18 | 35 | 5 | 28 | 27 | 4.5 | 22 | T3 | 241 | 508 |
| 1003-3 | 10 | 3 | 1.8 | 24 | 44 | 8 | 32 | 34 | 4.5 | 27 | T3 | 401 | 700 |
| 1004-3 | 10 | 4 | 2 | 26 | 46 | 10 | 35 | 36 | 4.5 | 28 | T3 | 468 | 798 |
| 1202-3 | 12 | 2 | 1.2 | 20 | 37 | 5 | 28 | 29 | 4.5 | 24 | T3 | 263 | 617 |
| 1204-3 | 12 | 4 | 2.381 | 28 | 48 | 6 | 35 | 39 | 5.5 | 30 | T3 | 645 | 1117 |
| 1205-3 | 12 | 5 | 2 | 28 | 48 | 6 | 35 | 39 | 5.5 | 30 | T3 | 506 | 952 |
| 1402-3 | 14 | 2 | 1.2 | 21 | 40 | 6 | 28 | 31 | 5.5 | 26 | T3 | 282 | 724 |
| 1602-3 | 16 | 2 | 1.2 | 25 | 43 | 10 | 32 | 35 | 5.5 | 29 | T3 | 301 | 837 |

# 6.9.10 FPA

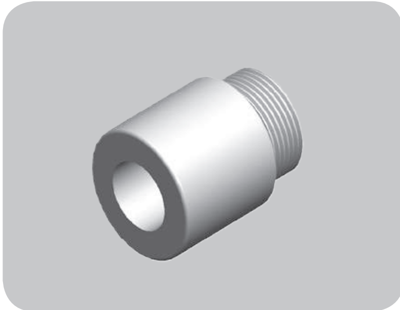


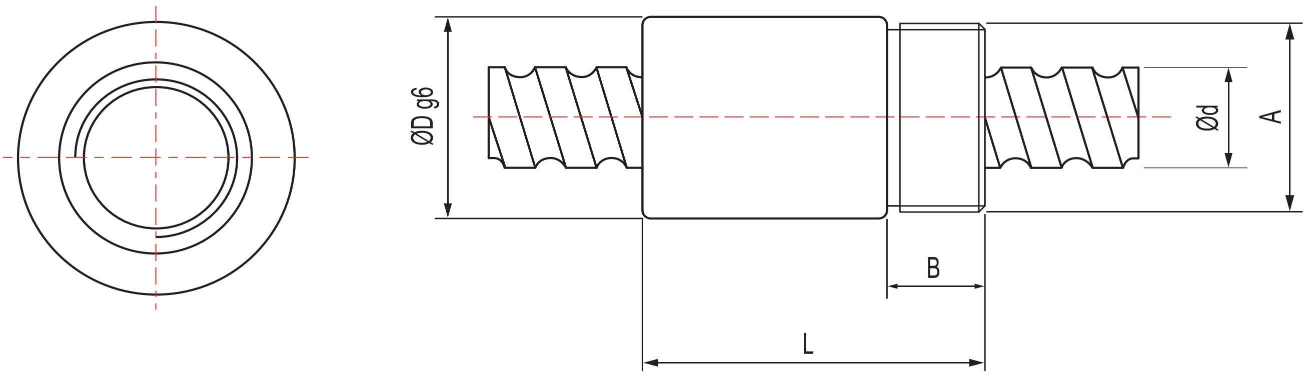



Unit : mm

| Model No. | Dimensions | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | l | Da | D | A | B | E | F | L | W | X | Y | Z | H1 | H2 | Q | n | Ca(Kgf) | Coa(kgf) |
| 1205-4 | 12 | 5 | 2 | 30 | 50 | 10 | 6 | 15 | 43 | 40 | 4.5 | 8 | 4.4 | 32 | 45 | M4 | T4 | 667 | 1426 |
| 1210-3 | 12 | 10 | 2 | 30 | 50 | 10 | 6 | 15 | 44 | 40 | 4.5 | 8 | 4.4 | 32 | 45 | M4 | T3 | 507 | 1022 |
| 1520-2 | 15 | 20 | 3.175 | 34 | 57 | 12 | 6 | 17 | 57 | 45 | 6 | 9.5 | 5.4 | 34 | 50 | M6 | T2 | 729 | 1353 |
| 1605-3 | 16 | 5 | 3.175 | 34 | 57 | 10 | 6 | 17 | 42 | 45 | 5.5 | 9.5 | 5.4 | 34 | 50 | M6 | T3 | 1063 | 1957 |
| 1610-3 | 16 | 10 | 3.175 | 34 | 57 | 11 | 6 | 17 | 44 | 45 | 5.5 | 9.5 | 5.4 | 34 | 50 | M6 | T3 | 1097 | 2245 |
| 2005-3 | 20 | 5 | 3.175 | 44 | 67 | 11 | 6 | 22 | 48 | 55 | 5.5 | 9.5 | 5.4 | 44 | 60 | M6 | T3 | 1192 | 2542 |
| 2010-3 | 20 | 10 | 3.969 | 46 | 74 | 13 | 6.5 | 24 | 54 | 59 | 6.6 | 11 | 6.5 | 46 | 66 | M6 | T3 | 1648 | 3554 |
| 2020-4 | 20 | 20 | 3.175 | 46 | 74 | 13 | 6.5 | 24 | 55 | 59 | 6.6 | 11 | 6.5 | 46 | 66 | M6 | T4 | 1497 | 3581 |

# 6.9.11 RSK( without wipers )

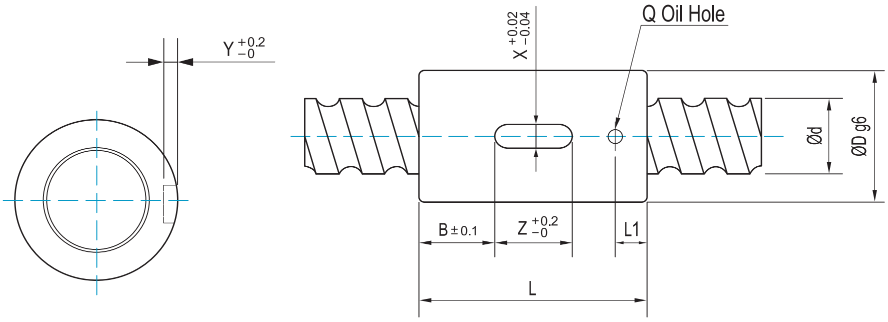


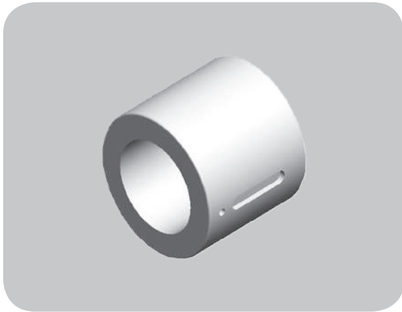



Unit : mm

| Model No. | Dimensions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | d | I | Da | D | A | B | L | n | Ca(Kgf) | Coa(kgf) |
| 0825-3 | 8 | 2.5 | 1.2 | 17.5 | M15X1P | 8 | 26 | T3 | 215 | 397 |
| 1003-3 | 10 | 3 | 1.8 | 21 | M18X1P | 9 | 29 | T3 | 401 | 700 |
| 1204-3 | 12 | 4 | 2.381 | 25.5 | M20X1P | 10 | 34 | T3 | 637 | 1117 |
| 1205-3 | 12 | 5 | 2 | 25.5 | M20X1P | 10 | 39 | T3 | 506 | 952 |
| 1605-3 | 16 | 5 | 3.175 | 32.5 | M26X1.5P | 12 | 42 | T3 | 1063 | 1957 |

# 6.9.12 RSY



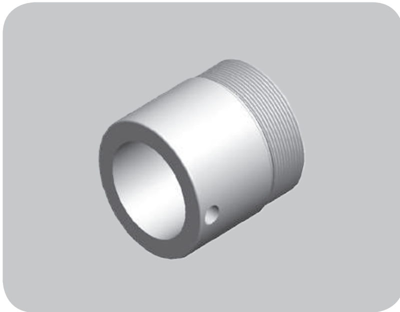



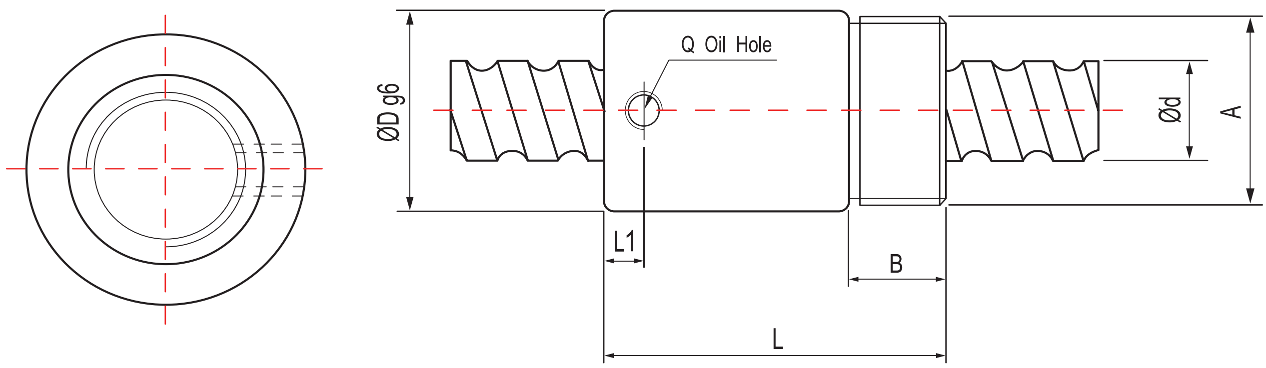
Unit : mm

| Model No. | Dimensions | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | I | Da | D | L | B | X | Y | Z | Q | L1 | n | (Ca Kgf) | (Coa (K |
| 1202-3 | 12 | 2 | 1.2 | 24 | 30 | 9 | 3 | 1.5 | 12 | Ø3 | 4 | T3 | 263 | 617 |
| 1204-3 | 12 | 4 | 2.381 | 24 | 35 | 11.5 | 3 | 1.5 | 12 | Ø3 | 5 | T3 | 637 | 1117 |
| 1205-3 | 12 | 5 | 2 | 24 | 40 | 14 | 3 | 1.5 | 12 | Ø3 | 5 | T3 | 506 | 952 |
| 1205-4 | 12 | 5 | 2 | 24 | 36 | 10 | 3 | 1.5 | 12 | Ø3 | 5 | T4 | 667 | 1426 |
| 1210-2 | 12 | 10 | 2 | 24 | 40 | 14 | 3 | 1.5 | 12 | Ø3 | 5 | T2 | 380 | 730 |
| 1602-3 | 16 | 2 | 1.2 | 28 | 40 | 10 | 5 | 2 | 20 | Ø3 | 5 | T3 | 301 | 837 |
| 1604-4 | 16 | 4 | 2.381 | 28 | 45 | 12.5 | 5 | 2 | 20 | Ø3 | 7 | T4 | 939 | 2048 |
| 1605-3 | 16 | 5 | 3.175 | 28 | 45 | 12.5 | 5 | 2 | 20 | Ø3 | 7 | T3 | 1063 | 1957 |
| ★1605-4 | 16 | 5 | 3.175 | 28 | 50 | 15 | 5 | 2 | 20 | Ø3 | 7 | T4 | 1361 | 2609 |
| 1610-3 | 16 | 10 | 3.175 | 28 | 45 | 12.5 | 5 | 2 | 20 | Ø3 | 7 | T3 | 1164 | 2405 |
| 1616-2 | 16 | 16 | 3.175 | 28 | 45 | 12.5 | 5 | 2 | 20 | Ø3 | 7 | T2 | 821 | 1603 |
| 2005-3 | 20 | 5 | 3.175 | 36 | 47 | 13.5 | 5 | 2 | 20 | Ø3 | 7 | T3 | 1192 | 2542 |
| ★2005-4 | 20 | 5 | 3.175 | 36 | 53 | 16.5 | 5 | 2 | 20 | Ø3 | 7 | T4 | 1527 | 3390 |
| 2010-3 | 20 | 10 | 3.969 | 36 | 68 | 24 | 5 | 2 | 20 | Ø3 | 7 | T3 | 1749 | 3808 |
| 2020-4 | 20 | 20 | 3.175 | 36 | 55 | 17.5 | 5 | 2 | 20 | Ø3 | 7 | T4 | 1639 | 3979 |
| ★2505-4 | 25 | 5 | 3.175 | 40 | 53 | 16.5 | 5 | 2 | 20 | Ø3 | 7 | T4 | 1716 | 4357 |
| ▲2510-3 | 25 | 10 | 3.5 | 40 | 54 | 17 | 5 | 2 | 20 | Ø3 | 7 | T3 | 1614 | 4071 |
| ★3205-4 | 32 | 5 | 3.175 | 50 | 53 | 11.5 | 6 | 2.5 | 30 | Ø3 | 7 | T4 | 1932 | 5705 |
| 3210-3 | 32 | 10 | 6.35 | 50 | 70 | 20 | 6 | 2.5 | 30 | Ø3 | 7 | T3 | 3721 | 7924 |
| 3220-3 | 32 | 20 | 3.969 | 50 | 78 | 24 | 6 | 2.5 | 30 | Ø3 | 7 | T3 | 2136 | 5917 |
| ★4005-4 | 40 | 5 | 3.175 | 63 | 56 | 13 | 6 | 2.5 | 30 | Ø3 | 7 | T4 | 2147 | 7250 |
| 4010-3 | 40 | 10 | 6.35 | 63 | 80 | 25 | 6 | 2.5 | 30 | Ø3 | 7 | T3 | 4163 | 10227 |
| 4020-3 | 40 | 20 | 5.556 | 63 | 83 | 26.5 | 6 | 2.5 | 30 | Ø3 | 7 | T3 | 3746 | 10492 |
| 5010-3 | 50 | 10 | 6.35 | 75 | 82 | 23 | 6 | 2.5 | 36 | Ø3 | 7 | T3 | 4674 | 13126 |
| 6310-4 | 63 | 10 | 6.35 | 85 | 90 | 29 | 6 | 3.5 | 32 | Ø5 | 14 | T4 | 6727 | 22820 |

**Note:** 1. with sign ★ can produce left helix
2. Steel balls 3.5mm, please order 3.5mm shaft to meet

## 6.9.13 RSU



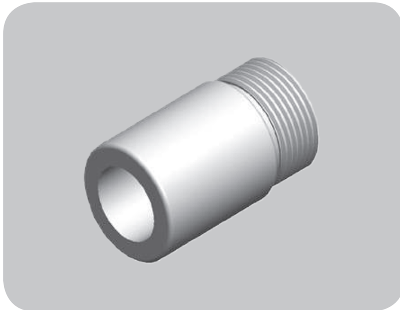


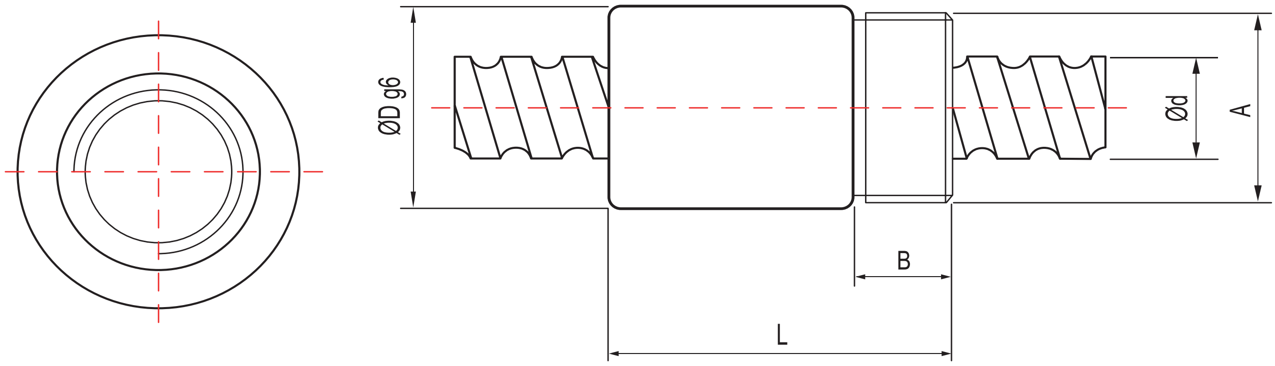

Unit : mm

| Model No. | Dimensions | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | I | Da | D | A | B | L | Q | L1 | n | Ca(Kgf) | Coa(kgf) |
| ▲ 1604-3 | 16 | 4 | 2.381 | 29 | M22X1.5P | 8 | 32 | - | - | T3 | 733 | 1536 |
| 1605-4 | 16 | 5 | 3.175 | 32 | M30X1.5P | 16 | 56 | M6 | 6.5 | T4 | 1361 | 2609 |
| 2005-4 | 20 | 5 | 3.175 | 38 | M35X1.5P | 16.5 | 59.5 | M6 | 7 | T4 | 1527 | 3390 |
| 2505-4 | 25 | 5 | 3.175 | 42 | M40X1.5P | 17 | 60 | M6 | 7 | T4 | 1716 | 4357 |
| 2510-4 | 25 | 10 | 4.762 | 42 | M40X1.5P | 17 | 90 | M6 | 10 | T4 | 2894 | 2610 |
| 3205-4 | 32 | 5 | 3.175 | 52 | M48X1.5P | 19 | 60 | M6 | 7 | T4 | 1932 | 5705 |
| 3210-4 | 32 | 10 | 6.35 | 52 | M48X1.5P | 19 | 93 | M6 | 12 | T4 | 4765 | 10565 |
| 4005-4 | 40 | 5 | 3.175 | 58 | M56X1.5P | 19 | 59 | M8 | 6 | T4 | 2174 | 7250 |
| 4010-4 | 40 | 10 | 6.35 | 65 | M60X1.5P | 27 | 102 | M8 | 12 | T4 | 5331 | 13636 |
| 5010-4 | 50 | 10 | 6.35 | 78 | M72X1.5P | 29 | 104 | M8 | 12 | T4 | 5986 | 17502 |

**Note:** ▲without wipers

# 6.9.14 RSH






Unit : mm

| Model No. | Dimensions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | d | l | Da | D | A | B | L | n | Ca(Kgf) | Coa(kgf) |
| 12H2-1.5 | 12 | 12.7 | 2.381 | 29.5 | M25x1.5P | 12 | 50 | A1 | 391 | 711 |
| 16H5-3.5 | 16 | 5.08 | 3.175 | 25.4 | 15/16”x16un | 12.7 | 43.43 | C1 | 1328 | 2805 |