Ball Screw



4.1 / Technological description of Ball Screws

4.1.1 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.4.1.1.1 Tolerance of deviation (± E) and variation (e) of accumlated reference travel are shown in Table 4.1.1.1~ 4.1.1.3

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 as e₃₀₀ of table 4.1.1.3 They are 0.05mm for C7 and 0.21mm for C10.





Table 4.1.1.1 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.
Р		Allowable value
а		Actual measured value.
т	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. Note: If no compensation is needed, specified travel is the same as nominal travel.
Е	Mean Travel Deviation	Mean Travel deviation is the difference between Mean Travel and Specified travel within travel length
е		Maximum width of variation over the travel length.
e 300	Travel	Actual width of variation for the length of 300mm taken anywhere within the travel length.
θ2π Variation		Wobble error, actual width of variation for one revolution(2π radian)



Table 4.1.1.2 Mean Travel Deviation (± E) and Travel Variation (e) (JIS B 1192)

	Grade		С	0	С	1	С	2	C	3	C	5	C7	C10	
	Over	Incl.	±Ε	е	±Ε	е	±Ε	е	±Ε	е	±Ε	е	е	е	
		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			
(mr	630	800	7	5	10	7	13	9	18	13	35	25			
:h(m	800	1000	8	6	11	8	15	10	21	15	40	27			
ngt	1000	1250	9	6	13	9	18	11	24	16	46	30			
I Le	1250	1600	11	7	15	10	21	13	29	18	54	35	±50	±210	
аvе	1600	2000			18	11	25	15	35	21	65	40	× 300mm	> 300mm	
Tr	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 4.1.1.3 Variation per 300mm (e300) and Wobble Error (e2 π) (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 π	3	4	4	6	8		

Miniature

Ball Screw

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4.1.2 Backlash in the Axial direction (customer demand)

	4.1.2.1 Maximum Backlash in the Axial direction (P0)			4	.1.2.2 Maximum Backl	ash in the Axial direction (P1)
Unit : mm						Unit : mm	
	Maximum Backlash	in the Axial direction			Maximum Backlash	in the Axial direction	
	Screw Shaft OD	Maximum Backlash in the Axial direction of Rolled Ball Screw			Screw Shaft OD	Maximum Backlash in the Axial direction of Rolled Ball Screw	
	4mm~14mm	0.05			4mm~80mm	0	
	15mm~50mm	0.08					
	50mm~80mm	0.12					

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

4.1.3 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.

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





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4.1.4 Preload torque

- Terms in relation to the preload torque generated during the rotation of the preload ball screws are shown in 4.1.4.1.
- Permissible ranges of torque variation rates is shown in 4.1.4.2.



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.

Standard

Ball Caged

Miniature

4.1.4.2 Permissible ranges of torque variation rates

		Effective threading length (mm)					
Reference		Belov	4000~10000				
kgf •	cm	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 $\boldsymbol{\cdot}$ cm) of the ball screws is given in following :

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

Where, Fao : Preload (Kgf)

eta : Lead angle

ℓ : 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.

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



4.2 / Screw shaft design

4.2.1 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 machines mounting methods for ball screws









Most common mounting methods for ball screws







.2.2 Buckling load

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.

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

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

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

- σ : Allowable tensile compressive stress (kgf $/ mm^2$)
- A : Sectional area (mm²) of screw shaft root bottom diameter
- dr : Screw shaft root diameter (mm)

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

Where,

- α : Safety factor (0.5)
- E: Vertical elastic modules ($E = 2.1 \times 10^4 \text{kgf/mm}^2$)
- I : Min. secondary moment of screw shaft sectional area

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

- 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)



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Screw

Ball

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4.2.3

Allowable rotation

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.

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 \leq 50,000 High lead seires dm.n \leq 130,000

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

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

Where,

n : Allowable rotation speed (rpm)

- α : Safety factor (0.8)
- E: Vertical elastic modules ($E = 2.1 \times 10^4 \text{kgf/mm}^2$)
- 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($g = 9.8 \times 10^3 \text{ mm} / \text{s}^2$)
- r : Density ($r = 7.8 \times 10^6$ kgf / mm³)
- A : Screw shaft sectional area ($A = \pi dr^2 / 4 mm^2$)
- L : Mounting distance (mm)
- $f \sim \lambda$: Coefficient determined from the Ball Screw mounting method

Support - Support $f = 9.7$	($\lambda = \pi$)
Fixed - Support $f = 15.1$	(<i>π</i> =3.927)
Fixed - Fixed $f = 21.9$	(<i>π</i> = 4.730)
Fixed - Free $f = 3.4$	$(\pi = 1.875)$





4.3 / Nut design

4.3.1 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.

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.

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.

4.3.1.1 External circulation type

Feature



Offers smoother ball running

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



Fig. 4.3.1.1 External circulation circular type.



Fig. 4.3.1.2 Internal diagram of the external circulation nut

Standard

Miniature

Screw

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4.3.1.2 Internal circulation type

Feature

The advantage of internal circulation type is that the outer diameter is smaller than that of external circulation type(Fig.4.3.1.3). Hence it is suitable for the machine with limit space for Ball Screw installation.

It should be noted that the screw shaft of the internal circulation ball screw must have one end fully threaded, and the shoulder diameter at that end must be smaller than the outer diameter of the screw shaft; otherwise, the nut cannot be assembled.



Fig. 4.3.1.3 Side view of the internal circulation



4.3.1.3 High lead type

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 hardness 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.

Internal diagram of the High lead circulation nut



4.3.2 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.

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

- P: Axial load borne by the transmission screw system (kgf)
- e: Axial flexural displacement (mm)

$$\frac{1}{K} = \frac{1}{K_{s}} + \frac{1}{K_{N}} + \frac{1}{K_{B}} + \frac{1}{K_{H}} (mm / kgf)$$

- Ks: Axial rigidity of screw shaft (1)
- K_N : Axial rigidity of nut (2)
- K_B : Axial rigidity of bracing shaft (3)
- $K_{\rm H}$: Axial rigidity of installation portions of nuts and bearings (4)
- (1) Axial rigidity Ks and displacement $\delta_{\rm S}$ of screw shaft

$$K_{s} = \frac{P}{\delta_{s}} (k_{g} f / \mu m)$$
$$P: \text{ Axial load (kgf)}$$

For places of Fixed - Fixed installation

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

For places other than Fixed - Fixed installation

$$\delta_{ss} = \frac{PL_o}{AE}$$
 (mm)

 $\delta_{ss} = 4 \delta_{sF}$

- $\sigma_{\mbox{\tiny SF}}$: Direction displacement at places of fixed-fixed installation
- δ_{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 $(2.1 \times 10^4 kgf \,/mm^2)$
 - L : Distance between installations (mm)
 - L_0 : Distance between load applying points (mm)

(2) Axial rigidity K_{N} and displacement $\, \delta_{\,\text{N}}$ of nut

$$K_{N} = \frac{P}{\delta_{s}} (kgf/\mu m)$$

(a) In case of single nut

$$\delta_{\text{NS}} = \frac{K}{\sin\beta} \left(\frac{Q^2}{d} \right)^{\prime_3} \times \frac{1}{\zeta} (\mu \text{ m})$$
$$Q = \frac{P}{n \cdot \sin\beta} \text{ (kgf)}$$

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

- Q: Load of one steel ball (kgf)
- n : Number of steel ball
- k~:~Constant determined based on material, shape, dimensions $k \doteq~5.7 \times 10^4$
- β : Angle of contact (45°)
- P: Axial load (kgf)
- d: Steel ball diameter (mm)
- ζ : Accuracy, internal structure coefficient
- m : Effective number of balls
- Do : Steel ball center diameter (mm)
- ℓ: Lead (mm)
- α : Lead angle

$$\mathsf{D}_{\mathsf{O}} = \frac{\ell}{\tan \alpha \cdot \pi}$$

(b) In case of double nuts



Fig. 4.3.2.1 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. Screw

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

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

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

(Explanation of the rigidity of double nuts)

As shown in diagram Fig. 4.3.2.1 and 4.3.2.2, 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 $\delta_{\rm NS}$ of the single nut, we can obtain:

 $\delta_{o} = a P_{PL}^{2_{/_{3}}}$

While displacements of nuts A & B are

$$\delta_A = a P_{PL}^{2/2}$$

since displacements of nuts A & B generated due to exertion of external force P are equal, therefore

$$\delta_{A} - \delta_{0} = \delta_{0} - \delta_{0}$$

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
$$\delta B = 0$$

 $aP_{A}^{2_{i_{3}}} - aP_{PL}^{2_{i_{3}}} = aP_{PL}^{2_{i_{3}}}$

$$P_A = 2P_{PL}$$

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

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

$$\delta \circ = \frac{\delta_A}{2}$$

thus it can also be judged from Fig. 4.3.2.3 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.





(3) Axial rigidity K_B and displacement δ_{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.

$$\delta_{B} = \frac{2}{\sin\beta} \left(\frac{Q^{2}}{d} \right)^{1/3}$$
$$Q = \frac{P}{r \sin\beta} (kgf)$$

- Q : Load of one steel ball (kgf)
- β : Angle of contact (45°)
- d : Steel ball diameter (mm)
- ℓ_a : Effective distance of scroll
- P: Axial load (kgf)
- n: Number of steel ball
- (4) Axial rigidity K_H and displacement δ_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)



4.3.2.1 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) $Fa_6 = -\mu \times mg - f$

4.3.2.2 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:

$Fa_1 = mg + f + ma$
$Fa_2 = mg + f$
$Fa_3 = mg + f - ma$
$Fa_4 = mg - f - ma$
$Fa_5 = mg - f$
$Fa_6 = mg - f + ma$

Here

a : Acceleration

$$a = \frac{V_{\text{max}}}{t_a} \qquad V_{\text{max}} : \text{Rapid feed speed}$$

$$t_a : \text{Acceleration time}$$

$$m : \text{Total weight (table weight + work piece weight)}$$

- m: Total weight (table weight + work piece weight) μ : Sliding surface friction coefficient
- f: Non-load resistance



Vertital reciprocating moving mechanism

Here

$$a = \frac{V_{\max}}{t}$$
 V_{\max} : Rapid feed speed
 t : Acceleration time

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

- $\mu~$: Sliding surface friction coefficient
- f : Non-load resistance

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4.4 / Preload and effect

4.4.1 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.



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. 4.4.1.1 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. 4.4.1.1 Extensive preload

Relation between preload force and elastic deformation

Fig. 4.4.1.3 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 δ_{ao} .

 $\delta_{A} = \delta_{a0} + \delta_{a1}$ $\delta_{B} = \delta_{a0} - \delta_{a1}$

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 b. Single-nut method:

As that illustrated on Fig. 4.4.1.2 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. 4.4.1.2 Four point contact preload



Fig. 4.4.1.3 Double-nut positioning preload



It means F_a is offset with an amount F_a' 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 δ_{al} caused by the external axial force equals δ_{a0} , and the preload force applied to Nut B is completely released. The formula related the external axial force and elastic deformation is

$$\delta_{a0} = K \times Fao^{2i3} \text{ and } 2\delta_{a0} = K \times F_1^{2i}$$
$$(F_1 / Fao)^2 = (2\delta_{a0} / \delta_{a0}) = 2$$
$$F_1 = 2.8Fao = 3Fao$$

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. 4.4.1.5 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. 4.4.1.4 Positioning preload diagram



Fig. 4.4.1.5 Elastic displacement curve

4.4.2 Positioning accuracy

4.4.2.1 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.

4.4.2.2 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.

 $\Delta \mathbf{L}_{\theta} = \rho \cdot \theta \cdot L$

Here

- ΔL_{θ} : Thermal displacement (µm)
- ρ : Thermal-expansion coefficient (12µm/m°C)
- θ : 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

Support Unit

Standard

Ball Caged

Miniature

Ball Screw

Linear Guide

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4.5 / Life

4.5.1 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.

4.5.2 Fatigue life

The basic dynamic rate load (*C*_{*a*}) of the Ball Screw is used to calculate its fatigue life.

4.5.2.1 Basic dynamic rate load Ca

The basic dynamic rate load (C_a) is the revolution of 10⁶ 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.

4.5.2.2 Fatigue life

Calculation life:

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

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

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

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

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

Load factor fw

Vibration and impact	Velocity (V)	f_{W}
Light	V<15 (<i>m/min</i>)	1.0~1.2
Medium	15 <v<60 (m="" min)<="" td=""><td>1.2~1.5</td></v<60>	1.2~1.5
Heavy	V>60 (<i>m/min</i>)	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 ł	۱rs
Production machine	.10,000 H	nrs
Automatic controller	15,000 h	nrs
Surveying instruments	.15,000 h	nrs



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. 4.5.2.1) Mean load can be calculated by using equation :

$$F_{m} = \left(\frac{F_{l}^{3} \cdot n_{l} \cdot t_{l} + F_{2}^{3} \cdot n_{2} \cdot t_{2} + \dots + F_{n}^{3} \cdot n_{n} \cdot t_{n}}{n_{l} \cdot t_{l} + n_{2} \cdot t_{2} + \dots + n_{n} \cdot t_{n}}\right)$$

Mean rotation speed can be calculated by using equation :

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

Axial load
(kgf)Rotation speed
(rpm)Time ratio
(Sec) F_1 n_1 t_1 F_2 n_2 t_2 \vdots \vdots \vdots F_n n_n t_n

F

0

 F_{min}

Σnjtj

Fig. 4.5.2.2 Similar straight line's load

b. Similar straight line (Fig. 4.5.2.2)

When mean load variation curve is like similar straight line Fig.4.5.2.2. Mean rotational speed can be calculated by using equation.

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



Fig. 4.5.2.1 Gradational variation curve'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.4.5.2.3) Mean rotational speed can be calculated by using equation. $F_m = 0.65 F_{max}$
 - 2. When mean load variation curve is shown as the diagram below (Fig.4.5.2.4) Mean rotational speed can be calculated by using equation. $F_m = 0.75F_{max}$



Fig. 4.5.2.3 Variation like Sine's curve load (1)



Fig. 4.5.2.4 Variation like Sine's curve load (2)

Standard

Ball Caged

Miniature

Ball Screw

Support Unit

 F_{max}

 F_m

4.5.3

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

4.5.4 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

4.5.5 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.



4.5.6 Key points for Ball Screws selection and calculation

Key points for Ball Screws selection	Calculation 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.	Final disassembly ability 10 μ m/stroke Kinimal disassembly ability 10 μ m/stroke Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction Construction
 1. Setting of operation conditions (a) Machine service life time reckoning of H (hr) H=XXXX	 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 Speed/rotations Cutting Solution Solution

Linear Guide

Ball Screw

Key points for Ball Screws selection	Calculation for Ball Screws selection
2.Ball Screws lead stroke ℓ (mm) $\ell = \frac{\text{Fast feed stroke (m/min)} \times 1000}{\text{Max. Rotating speed (min^{-1})}}$ (mm)	2.Ball Screws lead stroke ℓ (mm) $\ell = \frac{10000}{1000} = 10$ (mm) Minimal disassembly $= \frac{10mm}{1000 \text{ stroke}} = 0.01 \text{ mm/stroke}$
3.Computation of average load Pe (kgf) $Pe = \left(\frac{P_{1}^{n}n_{1}t_{1} + P_{2}^{n}n_{2}t_{2} + \dots + P_{n}^{n}n_{n}t_{n}}{n_{1}t_{1} + n_{2}t_{2} + \dots + n_{n}t_{n}}\right)^{\frac{1}{3}}$ $Pe = \frac{2Pmax + Pmin}{3}$ $pe = 0.65 Pmax$ $pe = 0.75 Pmin$	3.Computation of average load Pe (kgf) Pe = $\left(\frac{70^{3} \times 1000 \times 10+170^{3} \times 600 \times 50+270^{3} \times 200 \times 30+370^{3} \times 100 \times 10}{1000 \times 10+600 \times 50+200 \times 30+100 \times 10}\right)^{1/3}$ = $\left(\frac{31.7 \times 10^{13}}{4.7 \times 10^{4}}\right)^{1/3}$ \Rightarrow 189 kgf
4.Average number of rotation nm $n_{m} = \frac{n_{1}t_{1} + n_{2}t_{2} + \dots + n_{n}t_{n}}{100}$	4.Average number of rotation nm $n_{m} = \frac{1000 \times 10+600 \times 50+200 \times 30+100 \times 10}{100}$ $= \frac{4.7 \times 10^{4}}{100}$ $= 470 \text{ min}^{-1}$
5.Calculation of required dynamic rated load Ca(kgf) Ca = Pe • fs	5.Calculation of required dynamic rated load Ca (kgf) Ca =189×5=945 (kgf)
6.Calculation of required static rated load Coa (kgf) Coa=Pmax • fs	6.Calculation of required static rated load Coa (kgf) Coa = 369×5 =1845 (kgf)
7.Selection of nut type Ca > 945 Coa > 1845 Select the nut types with basic dynamic rated load and basic static rated load as specified above.	7.Selection of nut type Choose SFI 4010 on the catalogue Ca = 3178 kgf Coa = 9480 kgf



Linear Guide

Ball Screw

Key points for Ball Screws selection	Calculation for Ball Screws selection	
8. Calculation of life confirmation L _t (h) $L_{t} = \left(\frac{Ca}{Pe \bullet fw}\right)^{3} \bullet \frac{1}{60 n_{m}} \bullet 10^{6}$	8. Calculation of life confirmation L _t (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	Standard
10. Mounting distance of screw length	10. Mounting distance of screw length (Fixed - Fixed)	Ball Caged
11. Permissible axial load	1200 11. Permissible axial load Omitted because of Fixed - Fixed	Miniature
12. Permissible revolution speed n and dm $n = \alpha \times \frac{-60\lambda^2}{2\pi L^2} \sqrt{\frac{Elg}{\gamma A}} = f \frac{dr}{L^2} \times 10^7 (rpm)$ dm = Shaft dia. X Maximal speed	12. Permissible revolution speed n and dm $n = \frac{21.9 \times 35.2 \times 10^{7}}{1200^{2}}$ = 5353min ⁻¹ > nmax dm = 40 × 1000 = 40000 < 50000	Ball Screw
13. Countermeasure against thermal $\Delta L_{\theta} = \rho \cdot \theta \cdot L$ Here $\Delta L_{\theta} : \text{Thermal displacement (} \mu m \text{)}$ $\rho : \text{Thermal-expansion coefficient (} 12\mu m/m^{\circ}C \text{)}$ $\theta : \text{Screw-shaft temperature change (} ^{\circ}C \text{)}$ $L : \text{ Ball screw length (mm)}$	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. $\Delta L_{\theta} = \rho \cdot \theta \cdot L$ $= 12 \times 10^{6} \times 2 \times 700 \text{ mm} \pm 0.0168 \text{ mm}$ $F_{P} = -\frac{EA\Delta L_{\theta}}{L}$ $= -\frac{2.06 \times 10^{4} \times \frac{\pi \times 35.2^{2}}{4} \times 0.0168}{700} \pm 481 \text{ kgf}$ Deviation can be corrected by estimating the temperature rise per extension of 0.0168 mm, and taking into consideration of the pre-tension of 481 kgf.	Support Unit

Key points for Ball Screws selection Calculation for Ball Screws selection 14. Rigidity review 14. Rigidity review (1) Axial rigidity Ks and displacement δ_{s} of screw shaft (1) Rigidity Ks = $\frac{P}{\delta s}$ (kgf/mm) $\delta_{\text{SF}} = \frac{\text{PL}}{\text{4AE}} = \frac{27 \times 1200}{4 \times \frac{\pi \times 35.2^2}{4} \times 2.06 \times 10^4}$ P = Axial load (kgf) = 0.00036 mn For places of Fixed - Fixed installation $Ks = \frac{370}{0.00036} = 10.3 \times 10^5 \text{ kgf} / \text{mm}$ $\delta_{SF} = \frac{PL}{4AE}$ (mm) (2) Rigidity of steel ball and nut groove (2) Axial rigidity KN and displacement δ_{N} of nut $n = \frac{41.8 \times \pi \times 2.5}{6.35} = 52$ $K_N = \frac{P}{O_S} (kgf / mm)$ $Q = \frac{370}{52 \sin 45^{\circ}} = 10$ In case of single nut $\delta_{\rm NS} = \frac{\rm K}{\sin\beta} \left(\frac{\rm Q^2}{\rm d}\right)^{1/3} \times \frac{\rm 1}{\zeta} \,(\,\rm mm)$ $\delta_{\rm NS} = \frac{0.00057}{\sin 45^{\circ}} \left(\frac{10^2}{6.35}\right)^{1/3} \times \frac{1}{0.7}$ $Q = \frac{P}{n \cdot \sin\beta}$ (kgf) $= 2.9 \times 10^{-3}$ mm $K_N = \frac{370}{2.9 \times 10^{-3}} = 1.28 \times 10^{5} \text{kgf/mm}$ $n = \frac{D_0 \pi m}{d}$ (each) (3) Rigidity of brancing bearings (3) Axial rigidity K_B and displacement δ_B of Support bearing Where, nut rigidity 50 kgf/mm $K_B = \frac{P}{\sqrt{B}} (\text{kgf} / \text{mm})$ $\delta_{B} = \frac{370}{50 \times 2} = 3.7 \ \mu \,\mathrm{m}$ $K_B = \frac{370}{0.0037} = 1 \times 10^5 \text{ kgf/mm}$ $\odot\,\delta$ total=0.36 + 2.9 + 3.7 = 6.96 $\,\mu$ m 15. Confirmation of the Ball Screw life 15. Confirmation of the Ball Screw life L = 20479(h) > 18000 (h)



4.6 **Driving torque**

Driving torque Ts of the transmission shaft

- (in fixed speed) $T_S = T_P + T_D + T_F$
- $T_{S} = T_{G} + T_{P} + T_{D} + T_{F}$ (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 Tg



$$\alpha = \frac{2\pi n}{60 \wedge t}$$
 (rad/s²)

- $J : Moment of inertia (kgf \cdot cm \cdot s^2)$
- α : Angular acceleration (rad/s²)
- n : Revolutions (min⁻¹)
- Δt : Starting time (sec)

Load torque T_P

 $\mathsf{T}_{\mathsf{P}} = \frac{\mathsf{P} \bullet \boldsymbol{\ell}}{2\pi\eta_1} \; (\mathsf{kgf} \bullet \mathsf{cm})$

 $P = F + \mu Mg$

- P : Axial load (kgf)
- e : lead (cm)
- η_1 : Positive efficiency
- The efficiency when rotating motion is altered to linear motion
- F : Cutting force (kgf)
- *μ* : Friction coefficient
- M: Mass of moving object (kg)
- g : Acceleration of gravity (9.8 m/s²)

$\mathsf{T}_{\mathsf{P}} = \frac{\mathsf{P} \bullet \ell \bullet \eta_2}{2\pi}$

 η_2 : Reverse efficiency

The efficiency when linear motion returns to rotating motion

3 Preload torque T_D

 $\frac{\mathsf{K}\bullet\;\mathsf{P}_{\mathsf{PL}}\bullet\;\boldsymbol{\ell}}{\sqrt{\tan\alpha}\bullet\!2\pi}\;\;(\mathsf{kgf}\bullet\mathsf{Cm})$ T_D =

- κ Internal coefficient (0.05 is usually adopted)
- P_{PL} : **Preload** (kgf)
- l : Lead (cm)
- α : Lead angle

4 Friction torque T_F

- $T_{F} = T_{B} + T_{O} + T_{J} (kgf \cdot cm)$
- T_B : Friction torque of bracing shaft
- To: Friction torque of free shaft
- TJ: 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

 $J = J_{BS} + J_{CU} + J_{W} + J_{M}$

- JBS : 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

Standard

Ball Caged

Miniature

Screw

Ball

Support Unit

Linear Guide

Conversion formula for moment of inertia of load

Formula Moment of inertia converted from motor shaft	J
Cylinder load	$\frac{\pi\rhoLD^4}{32}$
Linearly moving object	$\frac{M}{4} \left(\frac{V\ell}{\pi \bullet N_{\rm M}} \right)^2 = \frac{M}{4} \left(\frac{P}{\pi} \right)^2$
Unit	kg • m ²
Moment if inertia during deceleration	$J_{M} = \left(\frac{J\ell}{N_{M}}\right)^{2} \cdot J\ell$

- ρ : Density (kg / m³) ρ = 7.8×10³
- L : Cylinder length (m)
- D : Cylinder diameter (m)
- M : Mass of linear motion part (kg)
- $V\!\ell:~Velocity~of$ linearly moving object (m / min) $^{J_{M}:}$ Moment of inertia in motor direction
- Ne: Rotations in longitudinal moving direction (min⁻¹) Je: Moment of inertia in load direction

P : The moving magnitude of the linearly moving object

per every rotation of the motor (m)

N_M: Motor shaft revolutions (min⁻¹)



ABBA Ball Screw size list

Lead Dia.	1	2	2.5	3	4	5	5.08	6	10	12.7	16	20	25	32	40	50
6	۲															
8	۲	۲	۲													
10		۲		۲	۲											
12		۲			۲	۲			۲	۲						
14		۲			۲	۲										
15												۲				
16		۲			۲	۲	۲		۲		۲					
20						۲			۲			۲				
25					۲	۲			۲			۲	۲			
32						۲		۲	۲			۲		۲		
40						۲		۲	۲			۲			۲	
50									۲			۲				۲
63									۲			۲			۲	
80									۲			۲				

Rolled Ball Screw



Linear Guide

4.8 **Ordering key of Ball Screw**

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



4.9 Dimension of Ball Screw

4.9.1

FSU (DIN69051)









Unit : mm

Madal Na	Dimensions														
Model No.	d		Da	D	А	В	L	W	Х	Туре	Н	Q	n	Ca(Kgf)	Coa(kgf)
1204-4	12	4	2.381	24	40	10	40	32	4.5	А	30	M6	T4	816	1489
1604-4	16	4	2.381	28	48	10	45	38	5.5	А	40	M6	T4	939	2048
* 1605-3	16	5	3.175	28	48	10	42	38	5.5	А	40	M6	Т3	1063	1957
* 1605-4	16	5	3.175	28	48	10	50	38	5.5	А	40	M6	T4	1361	2609
2005-3	20	5	3.175	36	58	10	47	47	6.6	А	44	M6	Т3	1192	2542
* 2005-4	20	5	3.175	36	58	10	53	47	6.6	А	44	M6	T4	1527	3390
2006-3	20	6	3.969	36	58	10	52	47	6.6	А	44	M6	Т3	1589	3062
2010-3	20	10	3.969	36	58	10	68	47	6.6	А	44	M6	Т3	1603	3122
2504-4	25	4	2.381	40	62	11	46	51	6.6	А	48	M6	T4	1173	3350
2505-3	25	5	3.175	40	62	10	47	51	6.6	А	48	M6	Т3	1340	3268
* 2505-4	25	5	3.175	40	62	10	53	51	6.6	А	48	M6	T4	1716	4357
2510-3	25	10	4.762	40	62	12	75	51	6.6	А	48	M6	Т3	2260	4657
2510-4	25	10	4.762	40	62	12	85	51	6.6	А	48	M6	T4	2894	6210
★ 3205-4	32	5	3.175	50	80	12	53	65	9	А	62	M6	T4	1932	5705
3206-4	32	6	3.969	50	80	12	58	65	9	А	62	M6	T4	2592	6979
3210-3	32	10	6.35	50	80	16	77.5	65	9	А	62	M6	Т3	3721	7924
3210-4	32	10	6.35	50	80	16	90	65	9	А	62	M6	T4	4765	10565
★ 4005-4	40	5	3.175	63	93	16	56	78	9	В	70	M8	T4	2147	7250
4006-4	40	6	3.969	63	93	14	60	78	9	В	70	M6	T4	2880	8862
4010-4	40	10	6.35	63	93	18	93	78	9	В	70	M8	T4	5331	13636
5006-4	50	6	3.969	75	110	15	62	93	11	В	85	M8	T4	3208	11324
5010-4	50	10	6.35	75	110	18	93	93	11	В	85	M8	T4	5986	17502
6310-4	63	10	6.35	90	125	18	98	108	11	В	95	M8	T4	6727	22820
6320-3	63	20	9.525	95	135	20	138	115	13.5	В	100	M8	Т3	8931	24831
8010-4	80	10	6.35	105	145	20	98	125	13.5	В	110	M8	T4	7519	29386
8020-3	80	20	9.525	125	165	25	143	145	13.5	В	130	M8	Т3	10076	32217

Note: with sign \star can produce left helix



4.9.2 FDU (DIN69051)



Unit : mm

Linear Guide

Miniature

Ball Screw

Support Unit

Ball Screw

	Dimensions														
Model No.	d	I	Da	D	А	В	L	W	Х	Туре	Н	Q	n	Ca(Kgf)	Coa(kgf)
★ 1605-3	16	5	3.175	28	48	10	80	38	5.5	А	40	M6	Т3	1063	1957
★ 2005-4	20	5	3.175	36	58	12	92	47	6.6	А	44	M6	T4	1527	3390
★ 2505-4	25	5	3.175	40	62	12	92	51	6.6	А	48	M6	T4	1716	4357
2510-4	25	10	4.762	40	62	12	153	51	6.6	А	48	M6	T4	2896	6210
★ 3205-4	32	5	3.175	50	80	12	92	65	9	А	62	M6	T4	1932	5705
3210-4	32	10	6.35	50	80	16	160	65	9	А	62	M6	T4	4765	10565
4005-4	40	5	3.175	63	93	15	96	78	9	В	70	M8	T4	2147	7250
4010-4	40	10	6.35	63	93	18	162	78	9	В	70	M8	T4	5331	13636
5010-4	50	10	6.35	75	110	16	162	93	11	В	85	M8	T4	5986	17502
6310-4	63	10	6.35	90	125	18	182	108	11	В	95	M8	T4	6727	22820
6320-3	63	20	9.525	95	135	20	253	115	13.5	В	100	M8	Т3	8931	24831
8010-4	80	10	6.35	105	145	20	182	125	13.5	В	110	M8	T4	7519	29386
8020-3	80	20	9.525	125	165	25	253	145	13.5	В	130	M8	Т3	10076	32217

Note: with sign \star can produce left helix

4.9.3 FSI



Unit : mm

	Dimensions																
	d	I	Da	D	А	В	L	W	Х	Y	Z	Туре	Н	Q	n	Ca(Kgf)	Coa(kgf)
1404-4	14	4	2.381	26	46	10	47	36	4.5	8	4.5	А	34	M6	T4	880	1769
1405-3	14	5	3.175	26	46	10	45	36	4.5	8	4.5	А	34	M6	Т3	995	1686
★ 1604-4	16	4	2.381	30	49	10	45	39	4.5	8	4.5	А	34	M6	Τ4	939	2048
1605-3	16	5	3.175	30	49	10	42	39	4.5	8	4.5	A/B	34	M6	Т3	1063	1957
* 1605-4	16	5	3.175	30	49	10	50	39	4.5	8	4.5	A/B	34	M6	T4	1361	2609
1610-4	16	10	3.175	34	58	10	54.6	45	5.5	9.5	5.5	А	36	M6	Т4	1490	3207
* 2005-4	20	5	3.175	34	57	12	53	45	5.5	9.5	5.5	A/B	40	M6	Т4	1527	3390
2010-3	20	10	3.969	46	74	13	54	59	6.6	11	5.5	А	46	M6	Т3	1648	3554
2504-4	25	4	2.381	40	63	11	46	51	5.5	9.5	5.5	А	46	M6	Т4	1173	3350
* 2505-4	25	5	3.175	40	63	12	53	51	5.5	9.5	5.5	A/B	46	M8	Т4	1716	4357
2510-4	25	10	4.762	46	72	12	85	58	6.5	11	6.5	A/B	52	M6	T4	2894	6210
* 3205-4	32	5	3.175	46	72	12	53	58	6.5	11	6.5	A/B	52	M8	T4	1932	5705
3206-4	32	6	3.969	62	89	12	63	75	6.5	11	6.5	В	-	M8	T4	2592	6897
3210-4	32	10	6.35	54	88	16	90	70	9	14	8.5	A/B	62	M8	T4	4765	10565
* 4005-4	40	5	3.175	56	90	16	56	72	9	14	8.5	A/B	64	M8	T4	2147	7250
4010-4	40	10	6.35	62	104	18	93	82	11	17.5	11	A/B	70	M8	T4	5331	13636
5010-4	50	10	6.35	72	114	18	93	92	11	17.5	11	A/B	82	M8	T4	5986	17502
6310-4	63	10	6.35	85	131	22	100	107	14	20	13	В	-	M8	Т4	6727	22820
6320-3	63	20	9.525	95	153	23	130	123	18	26	17.5	В	-	M8	Т3	8931	24831
8010-4	80	10	6.35	105	150	22	92	127	14	20	13	В	-	M8	T4	7519	29386
8020-3	80	20	9.525	115	173	23	130	143	18	26	17.5	В	-	M8	Т3	10076	32217



4.9.4 FDI



<u>n</u>.....

Ball Caged

Miniature

Unit : mm

Support Unit

Model No									DILLE	ISION	5						
	d	I	Da	D	А	В	L	W	Х	Y	Z	Туре	Н	Q	n	Ca(Kgf)	Coa(kgf)
* 1605-3	16	5	3.175	30	49	10	80	39	4.5	8	4.5	А	34	M6	Т3	1063	1957
* 2005-4	20	5	3.175	34	57	12	92	45	5.5	9.5	5.5	А	40	M6	T4	1527	3390
* 2504-4	25	4	2.381	40	63	11	80	51	5.5	9.5	5.5	А	46	M6	T4	1173	3350
★ 2505-4	25	5	3.175	40	63	12	92	51	5.5	9.5	5.5	A/B	46	M8	T4	1716	4357
2510-4	25	10	4.762	46	72	12	156	58	6.5	11	6.5	А	52	M6	T4	2894	6210
★ 3205-4	32	5	3.175	46	72	12	92	58	6.5	11	6.5	А	52	M8	T4	1932	5705
3210-4	32	10	6.35	54	88	16	160	70	9	14	8.5	А	62	M8	T4	4765	10565
★ 4005-4	40	5	3.175	56	90	16	96	72	9	14	8.5	А	64	M8	T4	2147	7250
4010-4	40	10	6.35	62	104	18	162	82	11	17.5	11	А	70	M8	T4	5331	13636
5010-4	50	10	6.35	72	114	18	162	92	11	17.5	11	A/B	82	M8	T4	5986	17502
6310-4	63	10	6.35	85	131	22	182	107	14	20	13	В	-	M8	T4	6727	22820
6320-3	63	20	9.525	95	153	23	253	123	18	26	17.5	В	-	M8	Т3	8931	24831
8010-4	80	10	6.35	105	150	22	182	127	14	20	13	В	-	M8	T4	7519	29386
8020-3	80	20	9.525	115	173	23	253	143	18	26	17.5	В	-	M8	Т3	10076	32217

Note: with sign \star can produce left helix

4.9.5 FSC







90 g6









Unit : mm

Model No									Dim	ensio	ons						
	d		Da	D	А	В	L	W	Х	Y	Z	Туре	Н	Q	n	Ca(Kgf)	Coa(kgf)
1205-3	12	5	2	24	40	8	30	32	3.6	-	-	D	25	-	Т3	513	1051
1210-2	12	10	2	30	50	10	40	40	4.5	8	4.5	С	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	-	-	А	40	M6	Т3	1097	2245
1616-4	16	16	3.175	28	48	12	48	38	5.5	-	-	А	40	M6	T4	1361	2886
2010-3	20	10	3.969	36	44	10	48	47	6.6	-	-	А	44	M6	Т3	1648	3554
2525-4	25	25	3.969	47	74	12	67	60	6.6	-	-	А	56	M6	T4	2236	5590
3220-3	32	20	3.969	50	80	13	78	65	9	-	-	А	62	M6	Т3	2013	5522
3232-4	32	32	4.762	56	86	16	82	71	9	-	-	А	65	M6	Т4	3197	8612
4020-3	40	20	5.556	63	93	15	83	78	9	-	-	В	70	M8	Т3	3530	9793
4040-4	40	40	6.35	65	95	18	100	80	9	-	-	В	72	M8	Т4	5225	14404
5020-5	50	20	6.35	75	110	18	121	93	11	-	-	В	85	M8	T5	7401	23822
6310-6	63	10	6.35	90	135	20	94	108	13.5	-	-	В	100	M8	Т6	8170	31750

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



Standard

Ball Caged

Miniature

Ball Screw

Support Unit

Ball Screw

Linear Guide

4.9.6 FSS







Unit : mm

Madal Na									Dim	ensions					
	d		Da	D	А	В	L	W	Х	Туре	Н	Q	n	Ca(Kgf)	Coa(kgf)
1205-2.8	12	5	2	24	40	8	30	32	4.5	А	30	-	B1	513	1051
1210-1.8	12	10	2	24	40	8	34	32	4.5	А	30	-	A1	347	657
1605-3.8	15	5	2.778	28	48	10	36	38	5.5	А	40	M6	C1	1159	2514
1610-2.8	15	10	2.778	28	48	10	46	38	5.5	А	40	M6	B1	891	1852
1616-1.8	15	16	2.778	28	48	10	45	38	5.5	А	40	M6	A1	609	1191
1520-1.8	15	20	2.778	28	48	10	54	38	5.5	А	40	M6	A1	609	1191
2005-3.8	20	5	3.175	36	58	10	36	47	6.6	А	44	M6	C1	1584	3867
2010-3.8	20	10	3.175	36	58	10	56	47	6.6	А	44	M6	C1	1584	3867
2020-3.6	20	20	3.175	36	58	10	55	47	6.6	А	44	M6	A2	1497	3581
2510-3.8	25	10	3.5	40	62	10	64	51	6.6	А	48	M6	C1	1978	5157
2525-1.8	25	25	3.175	40	62	10	65	51	6.6	А	48	M6	A1	920	2266
3232-3.6	32	32	4.762	50	80	16	82	65	9	А	62	M6	A2	3197	8612
4040-3.6	40	40	6.35	63	93	18	100	78	9	В	70	M8	A2	5225	14404







U	۱n	It	2	m	۱m

	Dimensions														
Model No.	d	I	Da	D	A	В	Т	L	W	Х	Н	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
1632-1.6	16	32	2.778	32	53	10	10.1	42.5	42	4.5	34	M6	T2	566	1125
2040-1.6	20	40	3.175	39	62	10	13	51	50	5.5	41	M6	T2	748	1603
2550-1.6	25	50	3.969	47	74	12	15	58	60	6.6	49	M6	T2	1118	2507

Note: with sign \star can produce left helix





4.9.8

FSB

Unit : mm

Model No.	Dimensions													
MOUEI NO.	d	I	Da	D	А	В	L	W	Х	Н	Q	n	Ca(Kgf)	Coa(kgf)
1404-3	14	4	2.381	31	50	10	40	40	4.5	37	M6	Т3	687	1327
1405-3	14	5	3.175	32	50	10	45	40	4.5	38	M6	Т3	995	1686
1605-3	16	5	3.175	34	54	10	42	44	4.5	40	M6	Т3	1063	1957
2005-3	20	5	3.175	40	60	10	47	50	4.5	46	M6	Т3	1192	2542
2505-3	25	5	3.175	43	67	10	47	55	5.5	50	M6	Т3	1340	3268
2510-3	25	10	4.762	60	96	15	75	78	9	72	M6	Т3	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	Т3	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	Т4	5331	13636

 Ball Caged
 Standard

 Linear Guide
 Image: Standard

Miniature

Ball Screw

Support Unit





													Unit : mm
							Dime	nsions					
Model No.	d		Da	D	А	В	L	W	Х	Н	n	Ca(Kgf)	Coa(kgf)
0601-3	6	1	0.8	12	24	3.5	18	18	3.4	16	Т3	111	201
0801-3	8	1	0.8	14	27	4	20	21	3.4	18	Т3	126	272
0802-3	8	2	1.2	16	29	4	26	23	3.4	20	Т3	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	Т3	241	508
▲1003-3	10	3	1.8	24	44	8	32	34	4.5	27	Т3	401	700
1004-3	10	4	2	26	46	10	35	36	4.5	28	Т3	468	798
1202-3	12	2	1.2	20	37	5	28	29	4.5	24	Т3	263	617
1204-3	12	4	2.381	28	48	6	35	39	5.5	30	Т3	645	1117
1205-3	12	5	2	28	48	6	35	39	5.5	30	Т3	506	952
1402-3	14	2	1.2	21	40	6	28	31	5.5	26	Т3	282	724
1602-3	16	2	1.2	25	43	10	32	35	5.5	29	Т3	301	837

Note: A without wipers



4.9.10 FPA

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4-X thru ØY*Z dp

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Linear Guide **Ball Caged**

Standard

Miniature

Unit	:	mm

	Dimensions																		
wodel No.	d		Da	D	А	В	Ε	F	L	W	Х	Y	Ζ	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	Т3	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	Т3	1063	1957
1610-3	16	10	3.175	34	57	11	6	17	44	45	5.5	9.5	5.4	34	50	M6	Т3	1097	2245
2005-3	20	5	3.175	44	67	11	6	22	48	55	5.5	9.5	5.4	44	60	M6	Т3	1192	2542
2010-3	20	10	3.969	46	74	13	6.5	24	54	59	6.6	11	6.5	46	66	M6	Т3	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

96 DØ

Ball Screw Support Unit

4.9.11 RSK(without wipers)







Madal Na					Dim	ensions				
MODELINO.	d	I	Da	D	А	В	L	n	Ca(Kgf)	Coa(kgf)
0825-3	8	2.5	1.2	17.5	M15X1P	8	23.5	Т3	215	397
1003-3	10	3	1.8	21	M18X1P	9	29	Т3	401	700
1204-3	12	4	2.381	25.5	M20X1P	10	34	Т3	637	1117
1205-3	12	5	2	25.5	M20X1P	10	39	Т3	506	952
1605-3	16	5	3.175	32.5	M26X1.5P	12	42	Т3	1063	1957



4.9.12 RSY







ØD g6 pø

Unit : mm

Standard

Ball Caged

Miniature

Ball Screw

Support Unit

Ball Screw

Linear Guide

							D	imensi	ons					
Model No.	d	I	Da	D	L	В	Х	Y	Z	Q	L1	n	(Ca Kgf)	(Coa (Kgf)
1202-3	12	2	1.2	24	30	9	3	1.5	12	Ø3	4	Т3	263	617
1204-3	12	4	2.381	24	35	11.5	3	1.5	12	Ø3	5	Т3	637	1117
1205-3	12	5	2	24	40	14	3	1.5	12	Ø3	5	Т3	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	Т3	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	Т3	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	Т3	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	Т3	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	54	17	5	2	20	Ø3	7	Т3	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	Т3	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	Т3	3721	7924
3220-3	32	20	3.969	50	78	24	6	2.5	30	Ø3	7	Т3	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	Т3	4163	10227
4020-3	40	20	5.556	63	83	26.5	6	2.5	30	Ø3	7	Т3	3746	10492
5010-3	50	10	6.35	75	82	23	6	2.5	36	Ø3	7	Т3	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

4.9.13 RSU





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Madal Na						Dime	ensions					
	d		Da	D	А	В	L	Q	L1	n	Ca(Kgf)	Coa(kgf)
▲ 1604-3	16	4	2.381	29	M22X1.5P	8	32	-	-	Т3	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	M60X2P	27	102	M8	12	T4	5331	13636
5010-4	50	10	6.35	78	M72X2P	29	104	M8	12	T4	5986	17502

Note: A without wipers







Standard

RSH



Unit : mm

Model No					Dimer	isions				
Model No.	d	I	Da	D	А	В	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