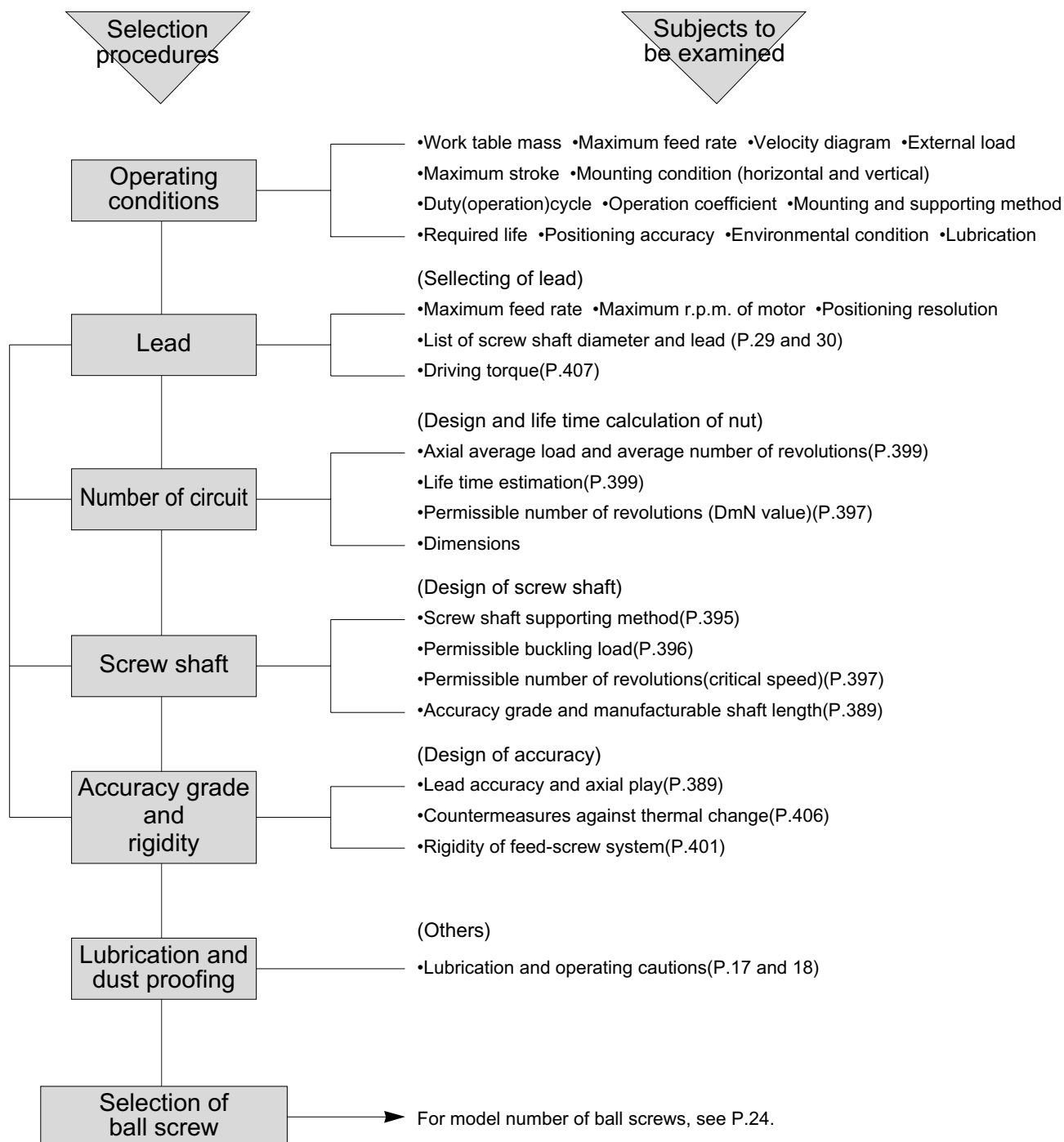


## GUIDE FOR BALL SCREW SELECTION

When a ball screw is selected, a number of factors are examined from various points of view on the basis of the above-mentioned basic subjects by a process of trial and error. Therefore, the procedure cannot be categorically determined. An example of general procedures and main subjects for examination regarding to each item and reference pages are mentioned below:



# TECHNICAL DATA OF BALL SCREWS

## •Example of ball screw selection

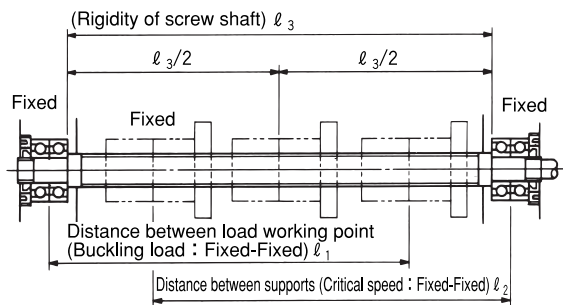
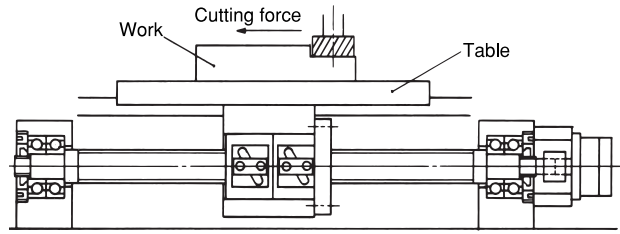
### •Machine tool

#### <Specifications>

- Mass of work and table  $M=1300(\text{kg})$
- Maximum stroke  $S_{\text{max}}=800(\text{mm})$
- Rapid traverse speed  $V_{\text{max}}=12000(\text{mm}/\text{min})$
- Linear guide coefficient of friction  $\mu=0.02$
- Load conditions

Classification	Axial load (N)	Feed speed (mm/min)	Operating time rate (%)
Rapid traverse speed	300	12000	25
Light/medium cutting	5000	600	55
Heavy cutting	9000	120	20

- Positioning accuracy  $\pm 0.04/800(\text{mm})$
- Required life time 25000(hour)
- Drive motor  $N_{\text{max}}=2000(\text{min}^{-1})$
- Shaft-end support method Fixed-Fixed



### 1. Selecting of lead(L)

Select the lead so that the maximum r.p.m. of motor and the rapid traverse speed of motor satisfy the following formula:

$$L \geq \frac{V_{\text{max}}}{N_{\text{max}}} = 6(\text{mm})$$

### 2. Design of nut

Examination of necessary basic dynamic load rating and permissible number of revolutions(DmN value).

#### <In the case of lead 6>

Load conditions

Classification	Axial load (N)	Number of revolutions (min <sup>-1</sup> )	Operating hour rate (%)
Rapid traverse speed	300	2000	25
Light/medium cutting	5000	100	55
Heavy cutting	9000	20	20

Calculating axial average load( $P_m$ )and average number of revolutions ( $N_m$ )from load conditions(formulas ⑥ and ⑦ on P.399)results in the following formulas:

$$P_m=2600(\text{N}) \quad N_m=559(\text{min}^{-1})$$

To calculate necessary basic dynamic load rating(C), transformation formula ⑤ shown in P.399 is used assuming that life time( $L_h$ )is 25000 hours and operation coefficient( $f_w$ )is 1.2.

$$C = \left( \frac{60L_h N_m}{10^6} \right)^{\frac{1}{3}} P_m f_w = 29420(\text{N})$$

A nut with suitable size and smallest diameter can be selected from P.370 as follows: **OD 36, lead 6 and 2.5 turns 3circuits.**

Then, when DmN value(formula ③ on P.397)is sought to find permissible number of revolutions,  $DmN=36.8 \times 2000=73600$  is found as against permissible  $DmN \leq 70000$ , showing that it exceeds the permissible value. Consequently, this size is not suitable. Therefore, increase the lead to 8, make the maximum number of revolutions lower and take another examination.

#### <In the case of lead 8>

Load conditions

Classification	Axial load (N)	Number of revolutions (min <sup>-1</sup> )	Operating time ratio (%)
Rapid traverse speed	300	1500	25
Light/medium cutting	5000	75	55
Heavy cutting	9000	15	20

When necessary basic dynamic load rating(C)is calculated in the same manner as in the case of lead 6, a nut with suitable size and smallest diameter can be selected from P.368 as follows:

$$P_m=2600(\text{N}) \quad N_m=419(\text{min}^{-1}) \quad C=26720(\text{N})$$

**OD 32, lead 8 and 2.5 turns 2 circuits.**

Then, DmN value is found to be  $DmN=33 \times 1500=49500$ , Showing that it satisfies the permissible value. Proceed with following examination based on this size.

### 3. Design of screw shaft

Examining overall length of screw shaft( $l$ ), permissible axial load( $P_0$ )and critical speed( $N_c$ )

Assuming that

$$l = \text{Maximum stroke} + \text{nut length} + \text{allowance} + \text{size of both shaft ends} \\ = 800 + 145 + 80 + 175 = 1200$$

To obtain permissible axial load, examine buckling load.

Assuming that distance between loading points  $l_1=930$ , the following formula can be obtained by formulas ① and ② on P.396:

$$P_0=141400(\text{N})$$

This can fully satisfy the operating conditions.

Critical speed is calculated from formula ④ on P.397 as follows:

$$N_c=6940(\text{min}^{-1})$$

Where, Distance between load working points  $l_2=940$

This can fully satisfy the operating conditions.

## 4. Rigidity of ball screw

Rigidity of screw shaft( $K_\ell$ )

Calculate at position  $\ell_3/2$  where axial deflection is maximized assuming that distance between bearing end faces  $\ell_3=1005$ . The following formula is obtained by formulas ⑩ and ⑪ on P.401:

$$K_\ell = \frac{E\pi d^2}{\ell_3} \times 10^{-3} = 50(\text{N}/\mu\text{m})$$

E: Young's modulus( $2.06 \times 10^5 \text{N}/\text{mm}^2$ )

d: Screw root diameter(mm)

Rigidity of nut( $K_{nw}$ )

Rigidity to any preload amount assuming that 1/3 of maximum axial load is preload( $P_L$ ) can be obtained using formula ⑫ on P.402.

$$K_{nw} = K_{NW} \left( \frac{P_L}{\frac{1}{15} C} \right)^{\frac{1}{3}}$$

$$= 59 \left( \frac{300}{\frac{1}{15} \times 3230} \right)^{\frac{1}{3}} = 660(\text{N}/\mu\text{m})$$

As the result of the above-mentioned examination, Nut Model Number **GR3208ED-DALR** is selected from P.368.

## 5. Selecting of accuracy

Select C5( $e_c = \pm 0.025$ ) from positioning accuracy  $\pm 0.04/800$  and permissible variable value( $e_c$ ) on P.389, assuming that the directivity of cumulative representative lead can be corrected on the control side.

## 6. Result of ball screw selection

Model number of the selected ball screw is

**GR3208ED-DALR-1200X0985-C5S** on P.368.

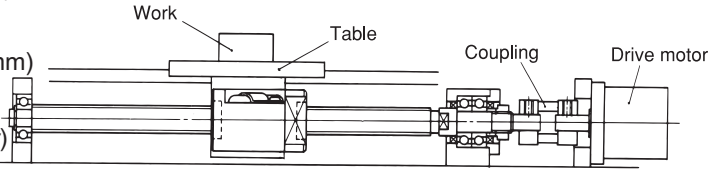
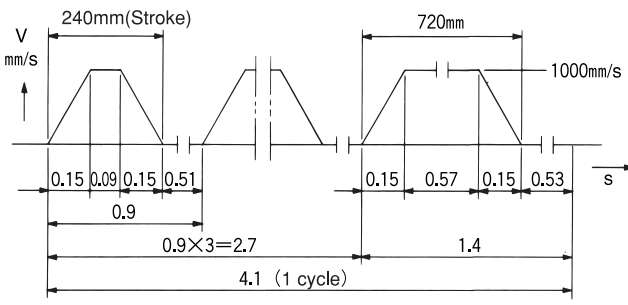
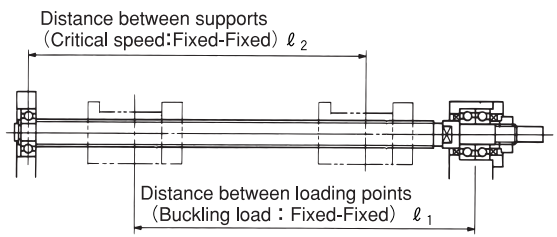
# TECHNICAL DATA OF BALL SCREWS

## •Example of ball screw selection

### •X-axis of Cartesian robot(Horizontal position)

<Specifications>

- Mass of work and table  $M=50(\text{kg})$
- Maximum stroke  $S_{\text{max}}=720(\text{mm})$
- Rapid traverse speed  $V_{\text{max}}=1000(\text{mm/s})$
- Acceleration and deceleration time constant  $t=0.15(\text{s})$
- Positioning accuracy  $\pm 0.1/720(\text{mm})$
- Repeatability  $\pm 0.01(\text{mm})$
- Required life time  $L_h=30000(\text{hour})$
- Linear guide coefficient of friction  $\mu=0.02$
- Drive motor  $N_{\text{max}}=3000(\text{min}^{-1})$
- Duty cycle model diagram

### 1. Selecting of lead(L)

Select the lead so that the maximum r.p.m. of motor and rapid traverse speed of motor satisfy the following formula:

$$L \geq \frac{V_{\text{max}} \times 60}{N_{\text{max}}} = 20(\text{mm})$$

### 2. Selecting of nut

Examination of necessary basic dynamic load rating and permissible number of revolutions(DmN value)

Calculation of axial load in each pattern of operation

① At the time of acceleration

$$\text{Acceleration}(\alpha) = \frac{V_{\text{max}}}{t} \times 10^{-3} = 6.7(\text{m/s}^2)$$

$$\text{Axial load}(P_a) = (M\alpha + \mu Mg) = 345(\text{N})$$

(g:Gravitational acceleration 9.8m/s<sup>2</sup>)

② At the time of fixed speed

$$\text{Axial load}(P_b) = \mu Mg = 1(\text{N})$$

③ At the time of deceleration

$$\text{Axial load}(P_c) = (M\alpha - \mu Mg) = 325(\text{N})$$

Operating time(s)during one cycle of each pattern

Pattern of operation	①	②	③	Total operating time
Operating time	0.6	0.84	0.6	2.04

### Load conditions at the time of lead 20

Pattern of operation	①	②	③
Axial load	343N	10N	324N
Number of revolutions	1500min <sup>-1</sup>	3000min <sup>-1</sup>	1500min <sup>-1</sup>
Operating time ratio	29.4%	41.2%	29.4%

Calculating axial average load(P<sub>m</sub>)and average number of revolutions(N<sub>m</sub>)from load conditions(formulas ⑥ and ⑦ on P.399)results in the following formulas:

$$P_m = 249(\text{N}) \quad N_m = 2118(\text{min}^{-1})$$

Calculating necessary basic dynamic load rating(C)

Net operation life time(L<sub>h0</sub>)excluding downtime from required life time is as follows:

$$L_{h0} = 30000 \left( \frac{2.04}{4.1} \right) = 14927(\text{hour})$$

Transformation formula ⑤ shown in P.399 is used

assuming that operation coefficient f<sub>w</sub>=1.2.

$$C = \left( \frac{60 L_{h0} N_m}{10^6} \right)^{\frac{1}{3}} \times P_m \times f_w = 3700(\text{N})$$

A ball screw with suitable size can be selected from standard ball screw GE and GG series(P.236)as follows:

OD 15, lead 20 and 1.5 turns 1 circuit.

When looking for DmN value(formula ③ on P.397)as a permissible number of revolutions, DmN=15.8X3000=47400 is found as against DmN≤70000, showing that it comes within the permissible value. Proceed with following examination based on this size.

### 3. Selecting of screw shaft

Examining overall length of screw shaft ( $l$ ), critical speed ( $N_c$ ) and buckling load ( $P_k$ )

Assuming that

$$l = \text{Maximum stroke} + \text{nut length} + \text{Safety stroke} + \text{size of both shaft ends} \\ = 720 + 62 + 60 + 78 = 920 \text{ (mm)}$$

To obtain permissible axial load, examine buckling load.

Assuming that distance between loading points  $l_1 = 820$ ,  $P_k = 7220$  (N) can be obtained by formulas ① and ② on P.396. This fully satisfies the operating condition.

Assuming that distance between supports  $l_2 = 790$ , critical speed can be obtained by formula ④ (Fixed-Supported) on P.397 as follows:

$$N_c = 3024 \text{ (min}^{-1}\text{)}$$

This satisfies the operating condition.

### 4. Setting of accuracy

Examination of accuracy grade and axial clearance

The accuracy grade that can satisfy positioning accuracy of  $\pm 0.1/750$  mm is determined from the permissible value of lead accuracy (P.389) and it becomes C5 (Cumulative representative lead error  $\pm E_c = 0.035$  and variation  $e_c = 0.025$ ). Axial play is set to 0.005 or less based on repeated positioning accuracy  $\pm 0.01$ .

### 5. Result of ball screw and support unit selection

When manufacturing them by additional machining of standard ball screw GG series with unworked shaft end, the following model number is selected from P.236:

**GG1520AS-BALR-1100A**

The model number of a suitable support unit selected from P.421 is **BUK-12.**

# TECHNICAL DATA OF BALL SCREWS

- Example of ball screw selection
- Elevator(Vertical position)

<Specifications>

- Mass of work and table  $M=100(\text{kg})$
- Maximum stroke  $S_{\text{max}}=1300(\text{mm})$
- Rapid traverse speed  $V_{\text{max}}=15000(\text{mm}/\text{min})$
- Acceleration and deceleration time constant  $t=0.5(\text{s})$
- Repeatability  $0.5(\text{mm})$
- Required life time  $L_h=20000(\text{hour})$
- Linear guide coefficient of friction  $\mu=0.02$
- Drive motor  $N_{\text{max}}=1500(\text{min}^{-1})$
- Duty cycle model diagram

## 1. Selecting of lead(L)

Select the lead so that the maximum r.p.m. of motor and rapid traverse speed of motor satisfy the following formula:

$$L \geq \frac{V_{\text{max}}}{N_{\text{max}}} = 10$$

## 2. Selecting of nut

Examination of necessary basic dynamic load rating and permissible number of revolutions(DmN value)

Calculation of axial load in each pattern of operation

- ① At the time of upward acceleration and downward deceleration

$$\text{Acceleration } \alpha = \frac{V_{\text{max}}}{t \cdot 60} \times 10^{-3} = 0.5(\text{m}/\text{s}^2)$$

$$\text{Axial load } P_a = (M\alpha + Mg) = 1030(\text{N})$$

(g:Gravitational acceleration 9.8m/s<sup>2</sup>)

- ② At the time of fixed speed

$$\text{Axial load } P_b = Mg = 980(\text{N})$$

- ③ At the time of upward deceleration and downward acceleration

$$\text{Axial load } P_c = (Mg - M\alpha) = 930(\text{N})$$

Operating time(s)during one cycle of each pattern

Pattern of operation	①	②	③	Total operating time
Operating time	1	9.4	1	11.4

Load conditions at the time of lead 10

Pattern of operation	①	②	③
Axial load	1030N	980N	930N
Number of revolutions	750min <sup>-1</sup>	1500min <sup>-1</sup>	750min <sup>-1</sup>
Operating time ratio	8.8%	82.4%	8.8%

Calculating axial average load(P<sub>m</sub>)and average number of revolutions(N<sub>m</sub>)from load conditions(formulas ⑥ and ⑦ on P.399)results in the following formulas:

$$P_m = 980(\text{N}) \quad N_m = 1368(\text{min}^{-1})$$

Calculating necessary basic dynamic load rating(C)

Net operation life time(L<sub>h0</sub>)excluding downtime from desired life time is as follows:

$$L_{h0} = L_h \left( \frac{11.4}{21.4} \right) = 10654(\text{hour})$$

As operation accompanies by vibration is anticipated, operation coefficient is calculated by transformation formula ⑤ shown in P.399, assuming that operation coefficient f<sub>w</sub>=1.5.

$$C = \left( \frac{60L_{h0}N_m}{10^6} \right)^{\frac{1}{3}} \times P_m \cdot f_w = 14057(\text{N})$$

Suitable nut size can be selected from rolled ball screw GY series U nut(P.102)based on repeatability 0.5 as follows:

**OD 25, lead 10 and 2.5 turns 2circuits.**

When looking for DmN value(formula ③ on P.397)as a permissible number of revolutions, DmN=26.8X1500=40200 is found as against DmN ≥ 50000, showing that it comes within the permissible value. Proceed with following examination based on this size.

### 3. Selecting of screw shaft

Examining overall length of screw shaft ( $l$ ) and permissible axial load ( $P_k$ )

$l$  = Maximum stroke + nut length + Safety stroke + size of both shaft ends

$$= 1300 + 92 + 60 + 118 = 1570 \text{ (mm)}$$

To obtain permissible axial load, examine buckling load.

Assuming that distance between load working points

$l_1 = 1440$ , the following formula can be obtained by formulas ① and ② (Fixed-Fixed) on P.396:

This satisfies the operating condition.

Assuming that distance between supports  $\delta_2 = 1420$ , the

following formula can be obtained formula ④ (Fixed-Supported) on P.397:

$$N_c = 1520 \text{ (min}^{-1}\text{)}$$

This satisfies the operating condition.

### 4. Result of ball screw selection

Provided that additional machining of rolled ball screw GY series U nut is performed, the following model number is selected from P.102:

GY2510ES-HULR-2000A