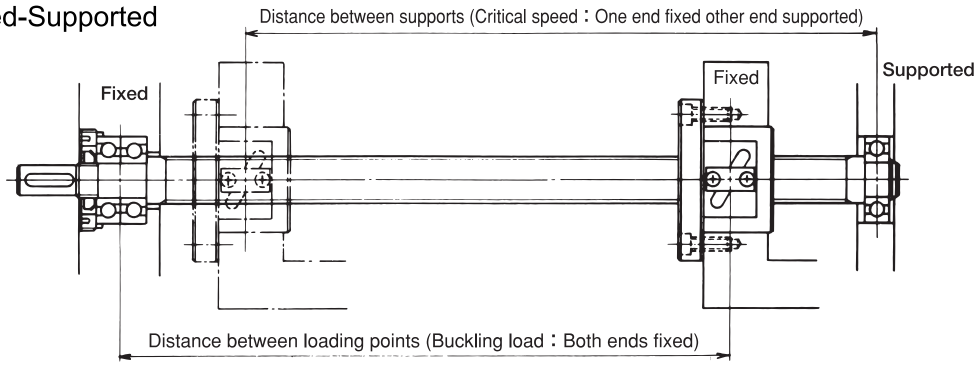
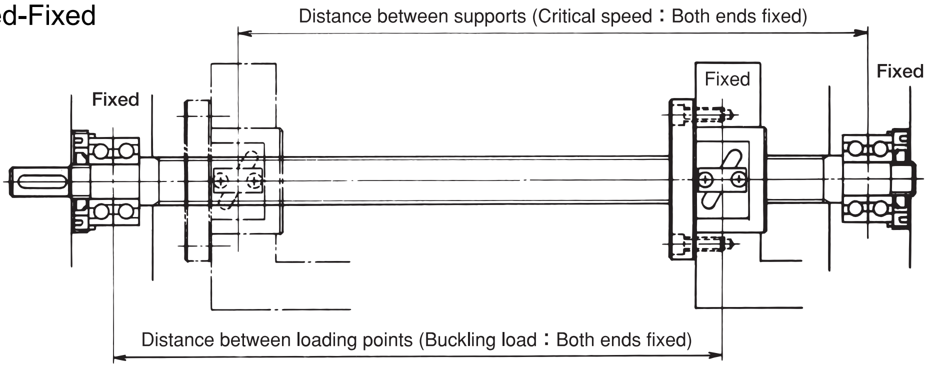
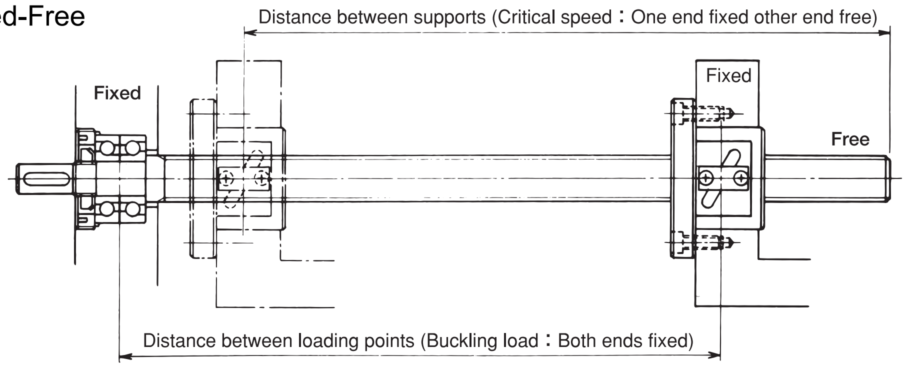
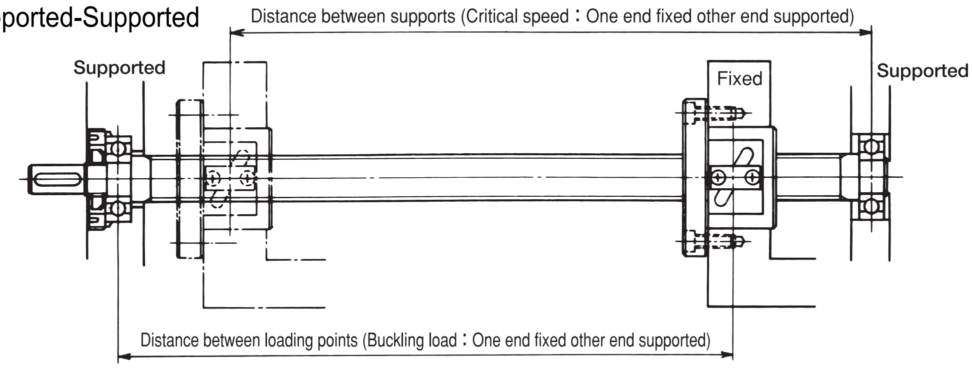
DESIGNING OF SCREW SHAFT

•MOUNTING METHODS FOR SCREW SHAFT

There are four basic methods of mounting shown as below. When heavy operation, screw shaft supporting method has a direct relation to permissible axial load and permissible number of rotations at critical speed.

<table>
<tr><th>Screw shaft supporting method</th><th>Application example</th></tr>
<tr><td>Fixed-Supported

</td><td>•Typical mounting method
•Medium to high speed range
•Medium accuracy to high accuracy</td></tr>
<tr><td>Fixed-Fixed

</td><td>•Medium speed
•High accuracy</td></tr>
<tr><td>Fixed-Free

</td><td>•Low speed
•Short shaft length
•Medium accuracy</td></tr>
<tr><td>Supported-Supported

</td><td>•Low to medium speed range
•Low accuracy</td></tr>
</table>

TECHNICAL DATA OF BALL SCREW

TECHNICAL DATA OF BALL SCREWS

•PERMISSIBLE AXIAL LOAD

A diagram of permissible axial load for selecting the minimum shaft diameter for the axial load is shown below.

(1)The oblique line indicates the permissible axial load determined by taking account of buckling of the screw shaft. Read a scale corresponding to the screw shaft supporting method.

(2)The line perallel to the line representing the distance between loading points indicates the permissible tensile/compression load. Read on the scale mark of "④ Supported-Supported".

(3)The line perpendicular to the line representing the Distance between loading points indicates the screw shaft length of ball screws manufacturable in the standard process in KURODA. (See Table 6 in Page 389.)

•Permissible axial load to buckling load:P

$$P=\alpha P_k \ \text{(N)} \quad \cdots\cdots ①$$

Where,

P_k:Bucking load (N)

α:Safety factor (α=0.5)

It may be sometimes necessary to set the safety factor at a larger value according to the degree of required safety.

Generally, the buckling load of a long column can be worked out from the Euler's equation.

However, when the slenderness ratio ℓ/k (k:Secondary radius of section) is 90 or less, use the Rankine's equation or the Tetmajer's equation.

•Buckling load worked out from Euler's equation

$$P_k=\frac{n\pi^2 EI}{\ell^2} \ \text{(N)} \quad \cdots\cdots ②$$

Where,

P_k:Load at which buckling starts (N)

ℓ : Distance between loading points (mm)

E: Young's modulus (2.06×10^5N/mm^2)

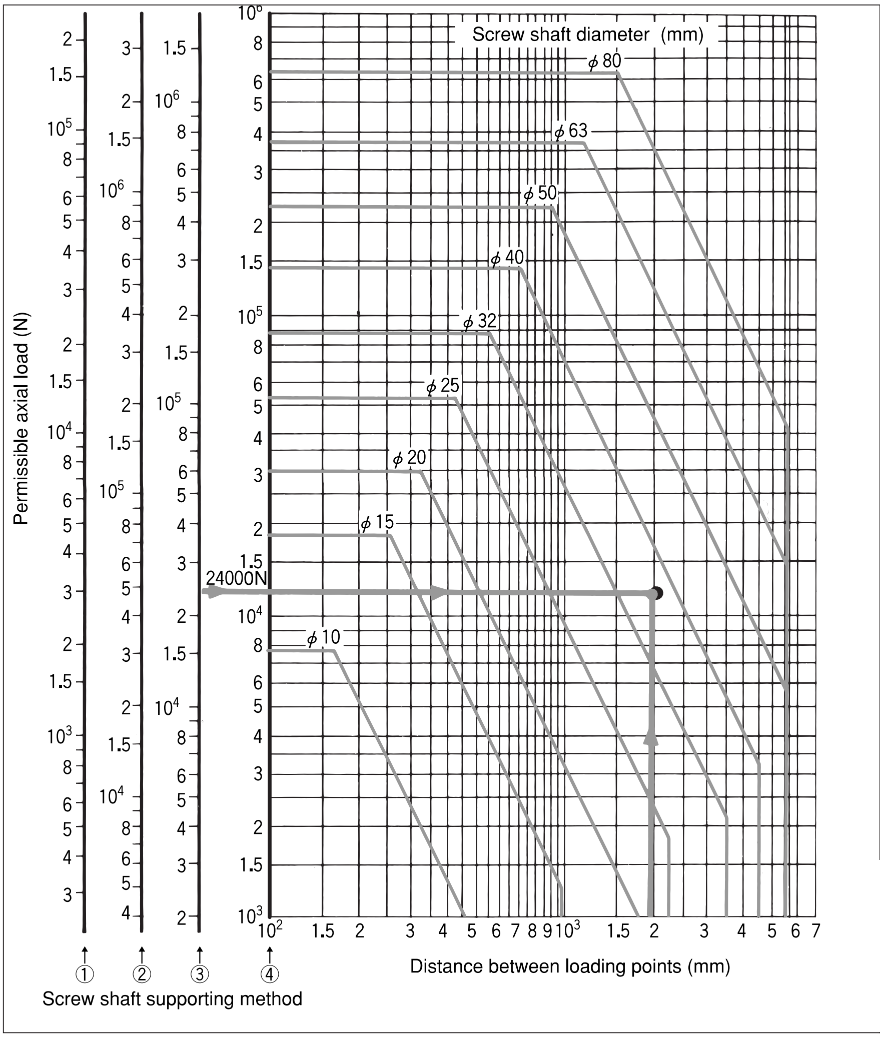
I: Minimum secondary moment of screw shaft root cross section (mm^4)

$$I=\frac{\pi}{64}d^4$$

d:Screw shaft root diameter (mm) Refer to Dimension Tables.

n:Coefficient to be determined by supporting method of ball screw

Supported-Supported	n=1
Fixed-Supported	n=2
Fixed-Fixed	n=4
Fixed-Free	n=0.25



Example

Selecting a shaft diameter when the screw shaft is supported with"Fixed-Supported"and a compession load of 24000N (maximum axial load) is applied to a distance of 2000mm as loading points (between nut and shaft end support)

1. Find out the intersecting point where the permissible axial compression load on the scale of"Fixed-Supported"is 24000N and the distance between loading points is 2000mm as shown by a thick line in Fig.7.
2. Then, select a shaft diameter of 40mm or more which is shown from the line outside the intersecting point.

Fig. 7 Diagram of permissible axial load

•PERMISSIBLE NUMBER OF REVOLUTIONS

The permissible number of revolutions of ball screws is expressed by DmN value which means the limit of operating speed of recirculating balls in the nut and the critical speed of the rotary shaft.

A diagram for selecting the optimum shaft diameter corresponding to the number of revolutions is shown in Fig. 8 on Page 398.

(1)The oblique line indicates the number of revolutions determined by taking account of the critical speed.
Read a scale corresponding to the screw shaft supporting method.

(2)The line parallel to the line representing the distance between supports is prepared on the basis of DmN value which is the limit of operating speed.
Read on the scale mark of "④ Supported-Supported".

(3)The line perpendicular to the line representing the distance between supports indicates the screw shaft length of ball screws that can be manufactured in the standard process by KURODA. (See Table 6 on Page 389.)

•DmN value

[Ground ball screw]

$DmN \leq 70000$..③

[Rolled ball screw]

$DmN \leq 50000$..③

Where,

Dm:Screw shaft diameter (mm)+A

N: Maximum number of revolutions (min^{-1})

Ball dia.	A
0.8	0.24
1.0	0.3
1.5875	0.3
2.0	0.4
2.3812	0.6
3.175	0.8
3.9688	0.8
4.7625	1.0
6.35	1.8
7.1438	2.0
7.9375	2.0
9.525	2.4

Consult KURODA for high speed consideration if the DmN on your application exceeds above mentioned value.

•Critical speed Nc

$$N_c = f_a \frac{60\lambda^2}{2\pi\ell^2}\sqrt{\frac{10^3EI}{\gamma A}} X10^2 (min^{-1}) .... ④$$

Where,

ℓ :Distance between supports (mm)

f_a:Safety factor

E:Young's modulus ($2.06X10^5 N/mm^2$)

I:Minimum secondary moment of screw shaft root cross section (mm^4)

$$I = \frac{\pi}{64} d^4$$

d:Screw shaft root diameter (mm)
Refer to Dimension Tables.

γ:Specific gravity ($7.8X10^{-6} kg/mm^3$)

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

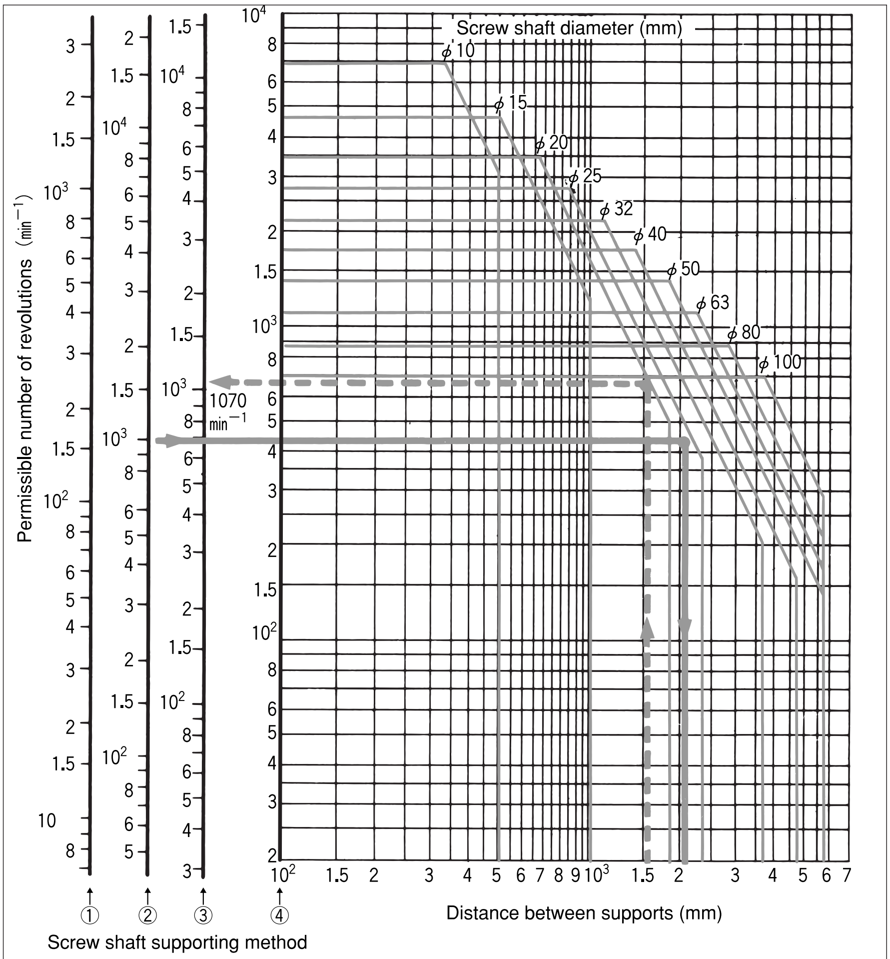
$$A = \frac{\pi}{4} d^2$$

λ:Factor to be determined according to the supporting method of ball screws;

Supported-Supported	$\lambda=\pi$
Fixed-Supported	$\lambda=3.927$
Fixed-Fixed	$\lambda=4.730$
Fixed-Free	$\lambda=1.875$

TECHNICAL DATA OF BALL SCREWS

Resonance phenomenon arising from the number of revolutions of a ball screw and the characteristic frequency of the screw shaft is caused by the unbalance of deflection by the empty weight of the shaft at the distance " ℓ " between supports of the rotation system and the critical speed corresponding to the characteristic frequency increases the amplitude of the vibration. When the ball screw is practically used, the nut serves as a move bearing, and therefore, the distance " ℓ " between supports always changes and the shaft deflection changes as well. Since the critical speed shown in Formula ④ is transient, consider it as a permissible number of revolutions to assure safety.



Screw shaft supporting method

① Fixed-Free

② Fixed-Fixed

③ Fixed-Supported

④ Supported-Supported

Fig. 8 Diagram of permissible number of revolutions

Example 1

Finding the maximum permissible number of revolutions, provided that the screw shaft is supported with"③Fixed-Supported", the shaft diameter is 20mm and the distance between supports is 1500mm:

1. The vertical thick line in Fig. 8 shows that the distance between supports is 1500mm. Find out an intersecting point with the oblique line representing the critical speed of the shaft with a diameter of 20mm.
2. In this case, the scale of the permissible number of revolutions for the supporting method of"③Fixed-Supported" reads 1076min^{-1}, which gives the maximum permissible number of revolutions.

Example 2

Finding a shaft diameter that can meet the maximum number of revolutions"1000min^{-1}", provided that the screw shaft is supported with "②Fixed-Fixed" and the distance between supports is 2000mm.

1. The vertical dotted line in Fig. 8 shows that the distance between supports is 2000mm. Find out an intersecting point with the line of the permissible number of revolutions "1000min^{-1}"on the scale of "②Fixed-Fixed".
2. In this case, a shaft diameter of 25mm meets the requirement.