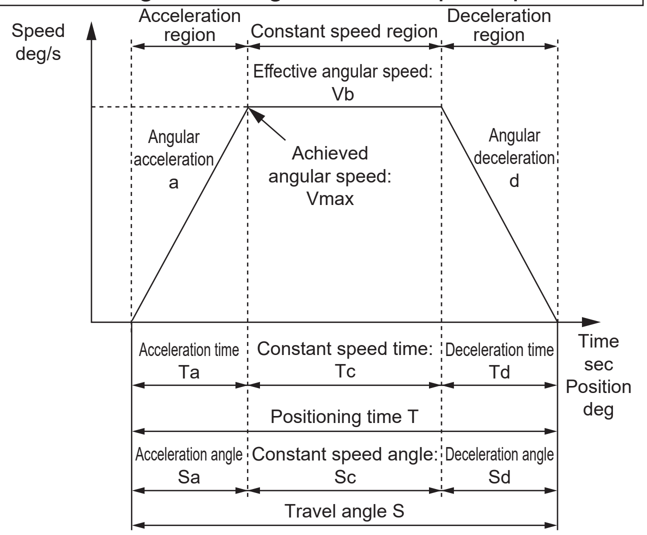
Model selection

STEP 1 Confirming positioning time

Calculate the positioning time with the selected product according to the following example and confirm that the required tact is attainable.

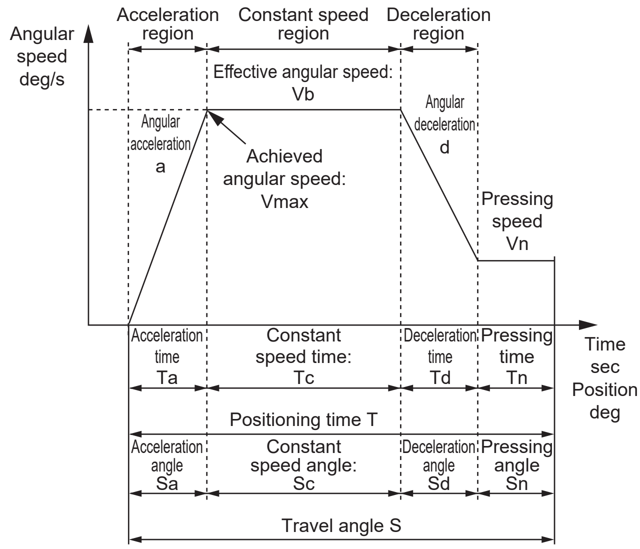
Positioning time for general transport operation



	Descriptions	Code	Unit	Remarks
Set value	Set angular speed	V	deg/s	
	Set angular acceleration	a	deg/s^2	
	Set angular deceleration	d	deg/s^2	
	Travel angle	S	deg	
Calculated value	Achieved angular speed	Vmax	deg/s	$= \{2 \times a \times d \times S/(a + d)\}^{1/2}$
	Effective angular speed	Vb	deg/s	The lesser value of V and Vmax
	Acceleration time	Ta	s	= Vb/a
	Deceleration time	Td	s	= Vb/d
	Constant speed time	Tc	s	= Sc/Vb
	Acceleration angle	Sa	deg	$= (a \times Ta^2)/2$
	Deceleration angle	Sd	deg	$= (d \times Td^2)/2$
	Constant speed angle	Sc	deg	= S - (Sa + Sd)
	Positioning time	T	s	= Ta + Tc + Td

* Do not use at angular speeds that exceed the specifications.
* Depending on angular acceleration/deceleration and travel angle, the trapezoid speed waveform may not be formed (the set angular speed may not be achieved).
In this case, select the effective angular speed (Vb) from the set angular speed (V) and the achieved angular speed (Vmax), whichever is smaller.
* Use at the angular acceleration/angular deceleration of 3000 deg/s^2 or less.
* While settling time depends on working conditions, it may take 0.2 seconds or so.
* 1G≒9800deg/s^2

Positioning time for pressing operation

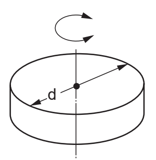
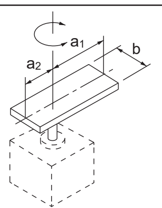


	Descriptions	Code	Unit	Remarks
Set value	Set angular speed	V	deg/s	
	Set angular acceleration	a	deg/s^2	
	Set angular deceleration	d	deg/s^2	
	Travel angle	S	deg	
	Pressing speed	Vn	deg/s	
	Pressing angle	Sn	deg	
Calculated value	Achieved angular speed	Vmax	deg/s	$=\{2 \times a \times d \times (S - Sn + Vn^2/2/d)/(a + d)\}^{1/2}$
	Effective angular speed	Vb	deg/s	The lesser value of V and Vmax
	Acceleration time	Ta	s	= Vb/a
	Deceleration time	Td	s	= (Vb - Vn)/d
	Constant speed time	Tc	s	= Sc/Vb
	Pressing time	Tn	s	= Sn/Vn
	Acceleration angle	Sa	deg	$= (a \times Ta^2)/2$
	Deceleration angle	Sd	deg	$= ((Vb + Vn) \times Td)/2$
	Constant speed angle	Sc	deg	= S - (Sa + Sd + Sn)
	Positioning time	T	s	= Ta + Tc + Td + Tn

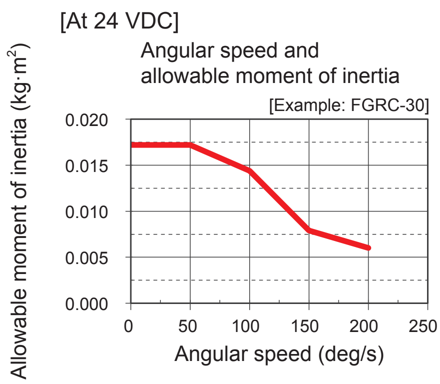
* Do not use at angular speeds that exceed the specifications.
* Depending on angular acceleration/deceleration and travel angle, the trapezoid speed waveform may not be formed (the set angular speed may not be achieved).
In this case, select the effective angular speed (Vb) from the set angular speed (V) and the achieved angular speed (Vmax), whichever is smaller.
* Use at the angular acceleration/angular deceleration of 3000 deg/s^2 or less.
* While settling time depends on working conditions, it may take 0.2 seconds or so.
* 1G≒9800deg/s^2

STEP 2 Confirming load moment of inertia

Calculate the load moment of inertia, and then select a model from the angular speed and allowable moment of inertia graph.

Shape	Sketch	Requirements	Moment of inertia I $kg \cdot m^2$	Radius of rotation
Dial plate		● Diameter d (m) ● Weight M (kg)	$I = \frac{Md^2}{8}$	$\frac{d^2}{8}$
Thin rectangle plate (rectangular parallelepiped)		●Plate length a_1, a_2 ●Side length b ●Weight M_1, M_2	$I = \frac{M_1}{12}(4a_1^2 + b^2) + \frac{M_2}{12}(4a_2^2 + b^2)$	$\frac{(4a_1^2 + b^2)+(4a_2^2 + b^2)}{12}$

*Refer to page 43.



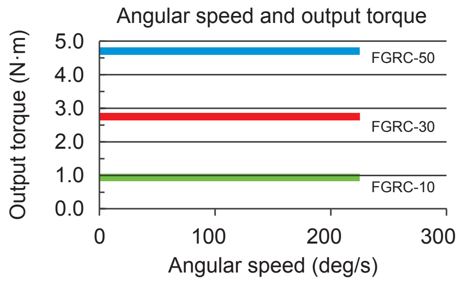
*Refer to pages 30, 32 and 34.

STEP 3 Confirming required torque

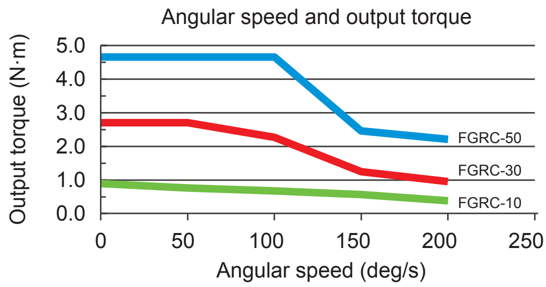
Use the following equations to determine the maximum load torque, and then refer to the angular speed and output torque graph to select the applicable model.

Selection method is roughly categorized into three load types.
In each case, the required torque must be calculated. If the load is a compound load, add each torque to calculate the required torque.

[At 48 VDC]



[At 24 VDC]



(1) Static load (T_S)
When static pushing force is required for clamp, etc.

$T_S = F_S \times L$

T_S: Required torque (N·m)
F_S: Required force (N)
L: Length from center of rotation to pressure cone apex (m)

(2) Resistance load (T_R)
When force including frictional force, gravity or other external force is applied

$T_R = 3 \times F_R \times L$

T_R: Required torque (N·m)
F_R: Required force (N)
L: Length from center of rotation to pressure cone apex (m)

(3) Inertia load (T_A)
When the object is rotated

$T_A = 3 \times I \times \dot{\omega}$

T_A: Required torque (N·m)
I: Moment of inertia (kg·m^2)
$\dot{\omega}$: Set angular acceleration/deceleration (rad/s^2)
θ: Travel angle (rad)
t: Travel time (s)
* Calculate $\dot{\omega}$ from angular acceleration or angular deceleration, whichever is higher.
The formula below can be used to determine the radian (rad) from the degree (deg).
rad = deg x (π/180)
Use the moment of inertia and travel time (pages 30, 32, and 34) or the figure for moment of inertia calculation (page 43) to calculate the moment of inertia.

STEP 4 Confirming allowable load

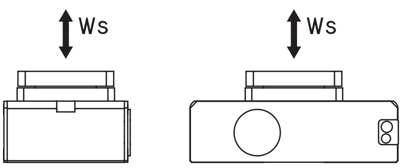
If load applies to table, load is to be within allowable value on Table 1.
For combined multiple load, ensure that the total is 1.0 or less.

Table 1

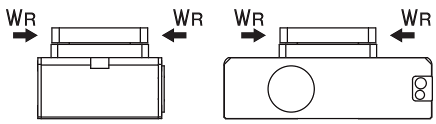
Model No.	W_S max	W_R max	M max
FGRC-10	80	80	2.5
FGRC-30	200	200	5.5
FGRC-50	450	320	10

W_S : Thrust load (N)
W_R : Radial load (N)
M : Moment load (N·m)
W_{Smax} : Allowable thrust load (N)
W_{Rmax} : Allowable radial load (N)
M_{max} : Allowable moment load (N·m)

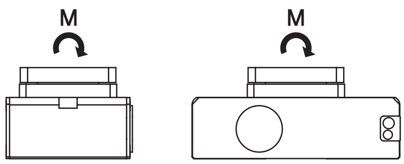
(1) Thrust load (axial load)



(2) Radial load (lateral load)



(3) Moment load



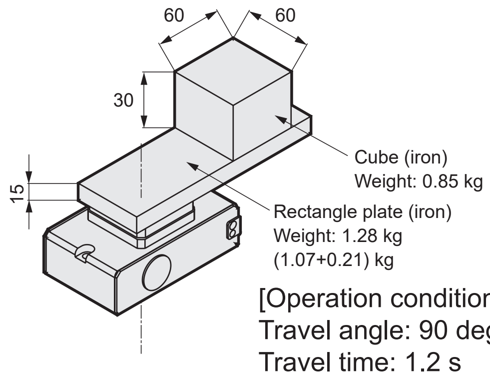
Combined load
Substitute the result to the following formula, and check after each load is calculated.

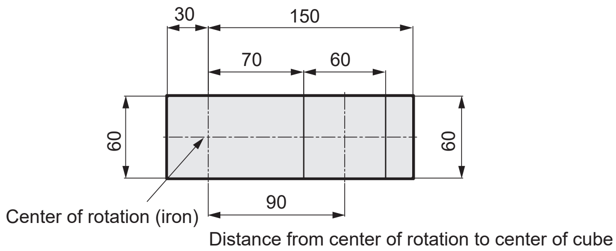
$$\frac{W_S}{W_{Smax}} + \frac{W_R}{W_{Rmax}} + \frac{M}{M_{max}} \le 1.0$$

FLSH
FLCR
FGRC
ECR (controller)
Safety precautions

FLSH
FLCR
FGRC
ECR (controller)
Safety precautions

Selection example [Horizontal]





[Operation conditions]
Travel angle: 90 deg
Travel time: 1.2 s
Angular acceleration/deceleration: 1000 deg/s^2 (0.1 G)

STEP 1 Confirming positioning time

Positioning time is 1.09 s according to operation conditions.
This is lower than the required travel time of 1.2 s, so proceed to the next step.

Set value

Angular speed	V	90 deg/s
Angular acceleration	a	1000 deg/s^2
Angular deceleration	d	1000 deg/s^2
Travel angle	S	90 deg

Calculated value

Achieved angular speed	Vmax	300 deg/s
Effective angular speed	Vb	90 deg/s
Acceleration time	Ta	0.09 s
Deceleration time	Td	0.09 s
Constant speed time	Tc	0.91 s
Positioning time	T	1.09 s

STEP 2 Confirming load moment of inertia

Calculate the moment of inertia I, and then temporarily select a model from the angular speed and allowable moment of inertia graph.

[Rectangle plate]

$$I1 = 1.07 \times \frac{4 \times 0.15^2 + 0.06^2}{12} + 0.21 \times \frac{4 \times 0.03^2 + 0.06^2}{12} = 0.00847$$

[Cube]

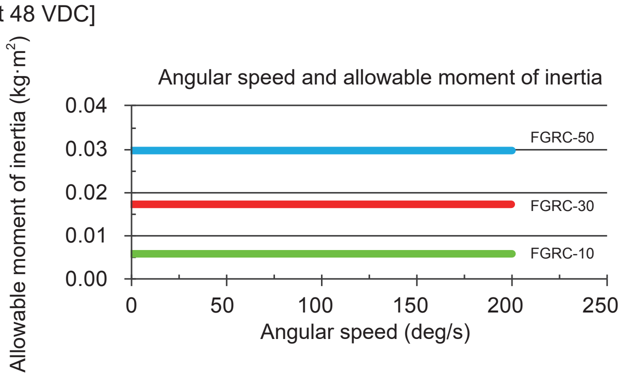
$$I2 = 0.85 \times \left[\frac{0.06^2 + 0.06^2}{12} + 0.09^2\right] = 0.00740$$

The overall moment of inertia I is as follows.

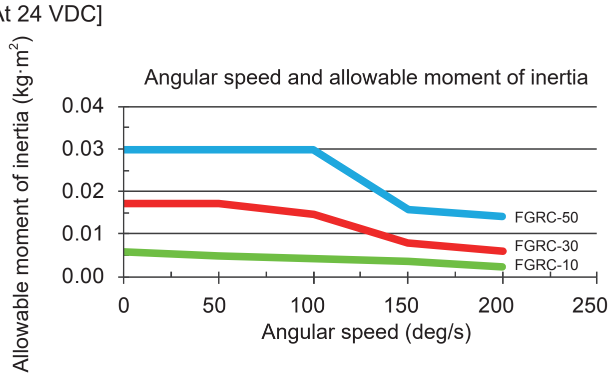
$$I = I1 + I2 = 0.01587\ (\mathrm{kg \cdot m^2}) \ldots\ldots (1)$$

From the graph of angular speed and allowable moment of inertia, select FGRC-30 [DC48V], which satisfies the allowable moment of inertia at angular speed 90 deg/s.

[At 48 VDC]



[At 24 VDC]



STEP 3 Confirming required torque

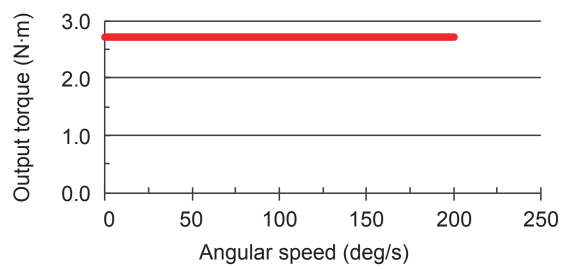
Calculate the load torque and confirm that it is within the range in the graph of angular speed and output torque.
Set acceleration/deceleration from a=d=1000 deg/s²

$$\dot{\omega} = 1000 \times \frac{\pi}{180}$$

$$= 17.45 \text{ rad/s}^2 \quad \text{......(2)}$$

From (1) and (2), inertia load (T_A) is
$T_A = 3 \times 0.01587 \times 17.45$
$= 0.831$ (N·m)

[48 VDC] <FGRC-30>

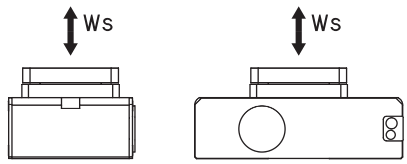


The intersection of angular speed V = 90 (deg/s) and T_A = 0.598 (N·m) is toward the interior of the graph, meaning use is possible.

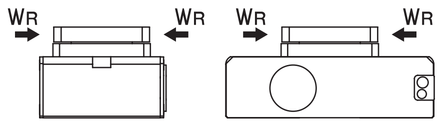
STEP 4 Confirming allowable load

Finally, check if value is within allowable load range after load value that applies to table is calculated.

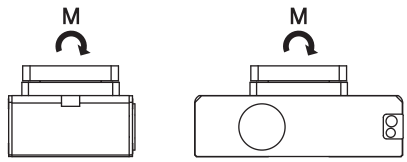
(1) Thrust load (axial load)



(2) Radial load (axial load)



(3) Moment load (axial load)



[Thrust load]
The total weight is
1.07 + 0.21 + 0.85 = 2.13 (kg)
Therefore, the thrust load (W_S) is
$W_S = 2.13 \times 9.8 = 20.9$ (N)

[Radial load]
Since no radial load is applied,
$W_R = 0$ (N)

[Moment load]
The moment load from the rectangle plate (M_1) is
$1.07 \times 9.8 = 10.5$ (N)
$0.21 \times 9.8 = 2.06$ (N)
Therefore,
$M_1 = 10.5 \times 0.075 - 2.06 \times 0.015 = 0.76$ (N·m)

The moment load from the rectangular parallelepiped (M_2) is
$0.85 \times 9.8 = 8.3$ (N)
Therefore,
$M_2 = 8.3 \times 0.09 = 0.75$ (N·m)

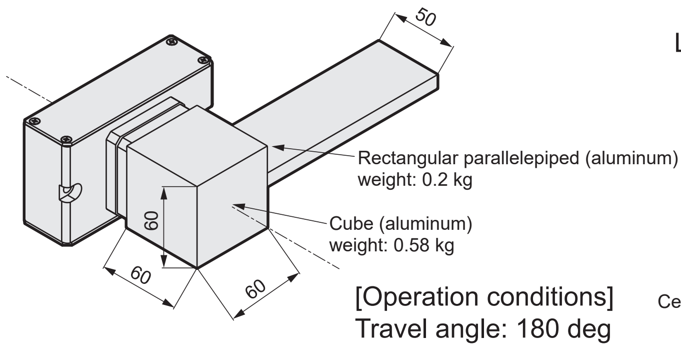
When M_1 and M_2 are totaled,
$M = 0.76 + 0.75 = 1.51$ (N·m)

$$\frac{W_S}{W_{S}max} + \frac{W_R}{W_{R}max} + \frac{M}{Mmax}$$

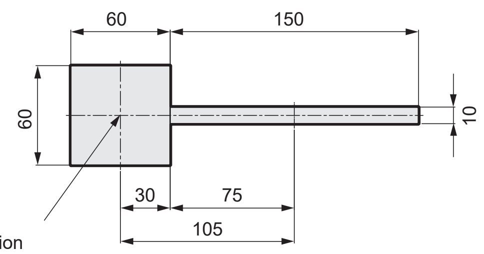
$$\frac{20.9}{200} + \frac{0}{200} + \frac{1.51}{5.5} = 0.4 \leq 1.0$$

The total load value is within the allowable load value,
so FGRC-30 can be selected.

Selection example [Wall-mounted]



Load details



(Distance from center of rotation to rectangle plate load center)

[Operation conditions]
Travel angle: 180 deg
Travel time: 1.8 s
Angular acceleration/deceleration: 1000 deg/s^2 (0.1 G)

STEP 1 Confirming positioning time

Positioning time is 1.57 s according to operation conditions.
This is lower than the required travel time of 1.8 s, so proceed to the next step.

Set value

Angular speed	V	125 deg/s
Angular acceleration	a	1000 deg/s^2
Angular deceleration	d	1000 deg/s^2
Travel angle	S	180 deg

Calculated value

Achieved angular speed	Vmax	424.3 deg/s
Effective angular speed	Vb	125 deg/s
Acceleration time	Ta	0.125 s
Deceleration time	Td	0.125 s
Constant speed time	Tc	1.315 s
Positioning time	T	1.57 s

STEP 2 Confirming load moment of inertia

Calculate the moment of inertia I, and then temporarily select a model from the angular speed and allowable moment of inertia graph.

[Rectangular parallelepiped]

$$I_1 = 0.2 \times \frac{(0.01^2 + 0.15^2)}{12} + 0.2 \times 0.105^2 = 0.00258 \ (\text{kg}\cdot\text{m}^2)$$

[Cube]

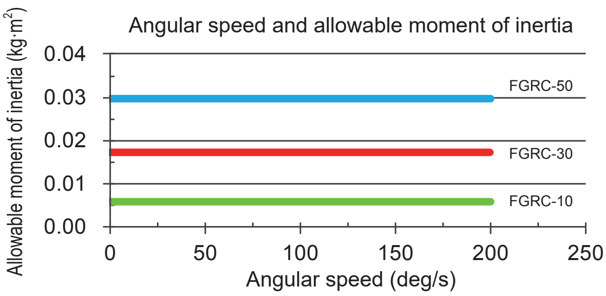
$$I_2 = 0.58 \times \frac{(0.06^2 + 0.06^2)}{12} = 0.00035 \ (\text{kg}\cdot\text{m}^2)$$

Therefore, the overall moment of inertia is as follows.

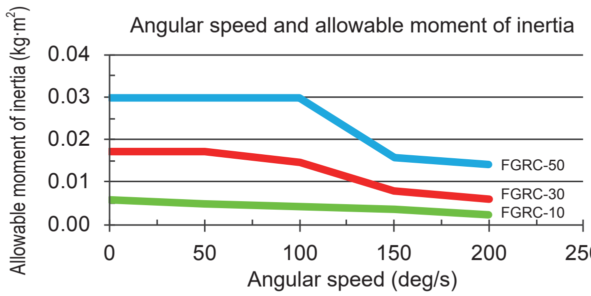
$I = I_1 + I_2 = 0.00293 \ (\text{kg}\cdot\text{m}^2)$...... (1)

From the graph of angular speed and allowable moment of inertia, select FGRC-10 [DC48V], which satisfies the allowable moment of inertia at angular speed 125 deg/s.

[At 48 VDC]



[At 24 VDC]



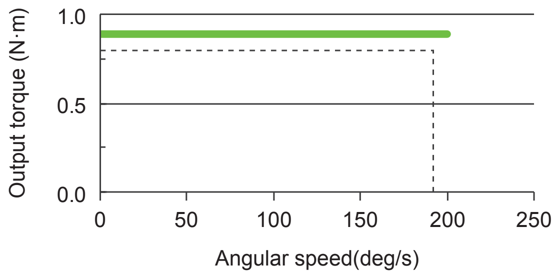
STEP 3 Confirming required torque

Calculate the load torque and confirm that it is within the range in the graph of angular speed and output torque.
Calculate the load torque using the gravitational resistance load (T_R) and inertia load (T_A).

[Resistance load]

$T_R = 3 \times 0.2 \times 9.8 \times 0.105$
$= 0.617$ (N·m) ……(2)

[48 VDC] <FGRC-10>



[Inertia load]

Set acceleration/deceleration from a = d = 1000 deg/s^2

$$\dot{\omega} = 1000 \times \frac{\pi}{180}$$

$= 17.45$ rad/s^2 ……(3)

From (1) and (3), inertia load (T_A) is
$T_A = 3 \times 0.00293 \times 17.45$
$= 0.153$ (N·m) ……(4)

From (2) and (4), total load torque (T) is
$T = T_R + T_A = 0.617 + 0.153 = 0.77$ (N·m)

The intersection of angular speed V=180(deg/s) and T=0.77(N·m) is toward the interior of the graph, meaning use is possible.

STEP 4 Confirming allowable load

Finally, check if value is within allowable load range after load value that applies to table is calculated.

[Thrust load]
Since no thrust load is applied,
$W_S = 0$ (N)

[Radial load]
The total weight is
0.2 + 0.58 = 0.78(kg)
Therefore, the radial load (W_R) is
$W_R = 0.78 \times 9.8 = 7.64$(N)

[Moment load]
Based on the figure to the lower right, the moment load (M) is
$M = 0.03 \times (0.2 + 0.58) \times 9.8 = 0.23$ (N·m)

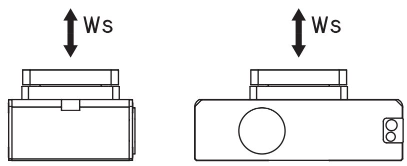
Therefore,

$$\frac{W_S}{W_{Smax}} + \frac{W_R}{W_{Rmax}} + \frac{M}{M_{max}}$$

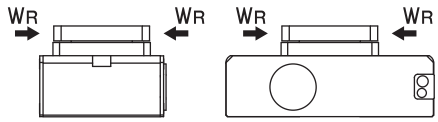
$$\frac{0}{80} + \frac{7.64}{80} + \frac{0.23}{2.5} = 0.19 \leq 1.0$$

Therefore, the total load value is within the total allowable load, so FGRC-10 can be selected.

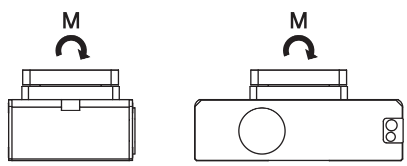
(1) Thrust load (axial load)



(2) Radial load (axial load)



(3) Moment load (axial load)



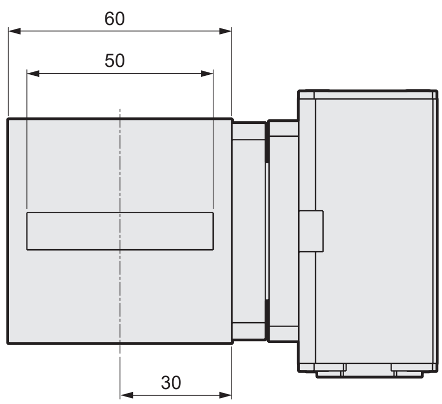
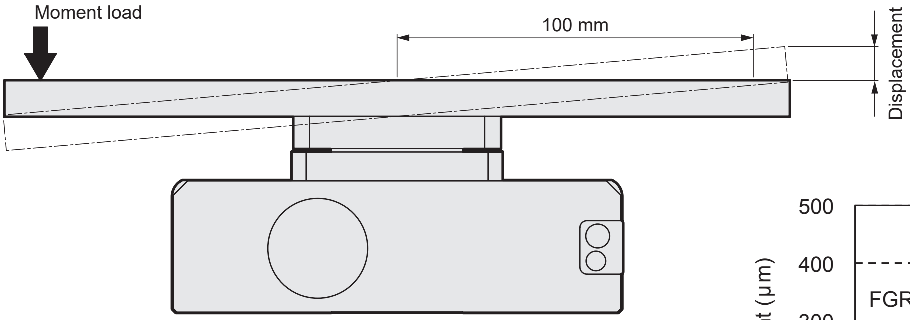
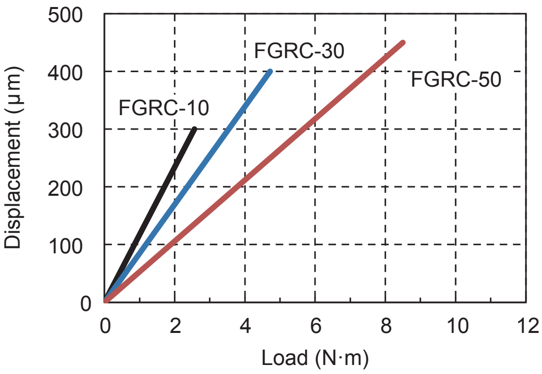


Table deflection *Reference value

Table deflection at 100 mm away from center of rotation when moment load is applied to FGRC.
(It is assumed that the table is in a non-rotating stationary state.)
Table deflection





Deflection: Displacement during 180° travel *Reference value

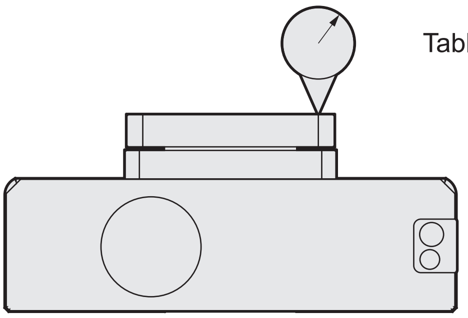


Table top runout

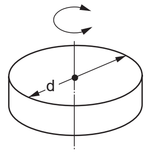
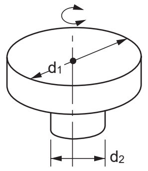
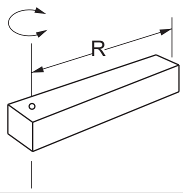
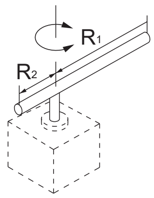
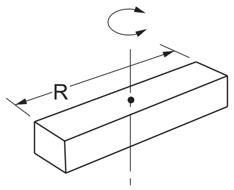
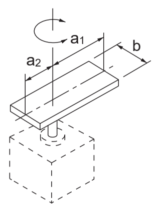
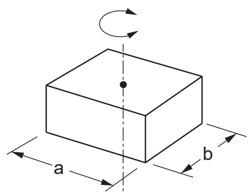
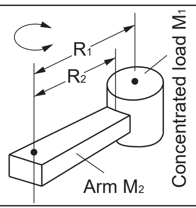
(mm)

Measurement location	FGRC
Table top runout	0.1

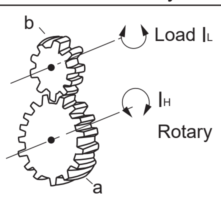
FLSH
FLCR
FGRC
ECR (controller)
Safety precautions

Figure for moment of inertia calculation

When rotary shaft passes through the workpiece

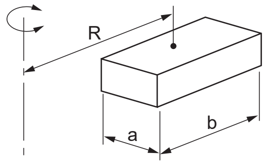
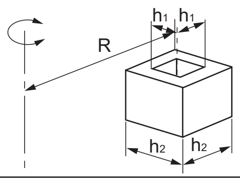
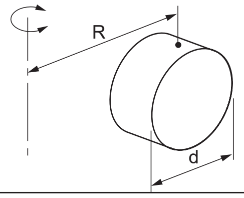
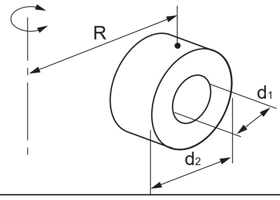
Shape	Sketch	Requirements	Moment of inertia I kg·m²	Radius of rotation K_1^2	Remarks
Dial plate		● Diameter d(m) ● Weight M(kg)	$I = \frac{Md^2}{8}$	$\frac{d^2}{8}$	● No mounting direction ● For sliding use, contact CKD.
Stepped dial plate		● Diameter d_1(m) d_2(m) ● Weight d_1 section M_1(kg) d_2 section M_2(kg)	$I = \frac{1}{8}(M_1d_1^2 + M_2d_2^2)$	$\frac{d_1^2 + d_2^2}{8}$	● Ignore when the d_2 section is extremely small compared to the d_1 section
Bar (center of rotation at end)		● Bar length R(m) ● Weight M(kg)	$I = \frac{MR^2}{3}$	$\frac{R^2}{3}$	● Mounting direction is horizontal ● Oscillating time changes when the mounting direction is vertical
Thin rod		● Bar length R_1 R_2 ● Weight M_1 M_2	$I = \frac{M_1/R_1^2}{3} + \frac{M_2/R_2^2}{3}$	$\frac{R_1^2 + R_2^2}{3}$	● Mounting direction is horizontal ● Oscillating time changes when the mounting direction is vertical
Bar (center of rotation at center of gravity)		● Bar length R (m) ● Weight M(kg)	$I = \frac{MR^2}{12}$	$\frac{R^2}{12}$	● No mounting direction
Thin rectangle plate (rectangular parallelepiped)		● Plate length a_1 a_2 ● Side length b ● Weight M_1 M_2	$I = \frac{M_1}{12}(4a_1^2 + b^2) + \frac{M_2}{12}(4a_2^2 + b^2)$	$\frac{(4a_1^2 + b^2) + (4a_2^2 + b^2)}{12}$	● Mounting direction is horizontal ● Oscillating time changes when the mounting direction is vertical
Rectangular parallelepiped		● Side length a(m) b(m) ● Weight M(kg)	$I = \frac{M}{12}(a^2 + b^2)$	$\frac{a^2 + b^2}{12}$	● No mounting direction ● For sliding use, contact CKD.
Concentrated load		● Shape of concentrated load ● Length to center of gravity of concentrated load R_1 ● Arm length R_2(m) ● Concentrated load weight M_1(kg) ● Arm weight M_2(kg)	$I = M_1(R_1^2 + k_1^2) + \frac{M_2R_2^2}{3}$	Calculate k_1^2 according to shape of concentrated load	● Mounting direction is horizontal ● When M2 is extremely small compared to M1, it may be calculated as M2 = 0

How to convert load J_L to rotary actuator shaft rotation when using with gear

Shape	Sketch	Requirements	Moment of inertia I kg·m²	Radius of rotation K_1^2	Remarks
Gear		● Gear Rotary side (No. of teeth) a Load side (No. of teeth) b ● Load moment of inertia N·m	Load moment of inertia for the rotary actuator's shaft rotation $I_H = \left(\frac{a}{b}\right)^2 I_L$		● When gear shape is larger, gear moment of inertia should be considered.

FLSH
FLCR
FGRC
ECR (controller)
Safety precautions

● Rotary shaft offsets from workpiece

Shape	Sketch	Requirements	Moment of inertia I kg·m²	Remarks
Rectangular parallelepiped		● Side length a(m) ● Distance from rotary shaft to load center b(m) R(m) ● Weight M(kg)	$I = \frac{M}{12}(a^2 + b^2) + MR^2$	● Same for cube
Hollow rectangular parallelepiped		● Side length h_1(m) h_2(m) ● Distance from rotary shaft to load center R(m) ● Weight M(kg)	$I = \frac{M}{12}(h_1^2 + h_2^2) + MR^2$	● Cross section is for cube only
Cylinder		● Diameter d(m) ● Distance from rotary shaft to load center R(m) ● Weight M(kg)	$I = \frac{Md^2}{16} + MR^2$	
Hollow cylinder		● Diameter d_1(m) d_2(m) ● Distance from rotary shaft to load center R(m) ● Weight M(kg)	$I = \frac{M}{16}(d_1^2 + d_2^2) + MR^2$	

* To find moment of inertia, first convert load, jig, etc., to simple shapes with modeling, then calculate values.
For the combined load, calculate each inertial moment and their total.