


### Applicable series:

MCRA, MCRB, MCRJ, MCRQ.

Moving the load with the actuator creates kinetic energy in the load. When stopping the moving load, it is necessary to absorb the kinetic energy of the load with a stopper or a shock absorber. The kinetic energy of the load can be calculated using the formulas shown in Figure 1 (for linear motion) and Figure 2 (for rotation motion).

### Linear motion

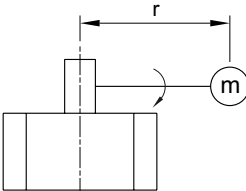


$E$  : Kinetic energy  
 $m$  : Load mass  
 $V$  : Speed

$$E = \frac{1}{2} \cdot m \cdot V^2 \dots (1)$$

Fig. (1) Linear motion

### Rotation motion



$E$  : Kinetic energy  
 $I$  : Moment of inertia ( $=m \cdot r^2$ )  
 $\omega$  : Speed  
 $m$  : Mass  
 $r$  : Radius of rotation

$$E = \frac{1}{2} \cdot I \cdot \omega^2 = \frac{1}{2} \cdot m \cdot r^2 \cdot \omega^2 \dots (2)$$

Fig. (2) Rotation motion

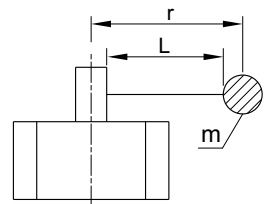
In the case of the kinetic energy for linear motion, the formula (1) shows that when the velocity  $v$  is constant, it is proportional to the mass  $m$ . In the case of rotation motion, the formula (2) shows that when the angular velocity is constant, it is proportional to the moment of inertia.

As the moment of inertia is proportional to the product of the mass and the square of the radius of rotation, even when the load mass is the same, the moment of inertia will be squared as the radius of rotation grows bigger. This will create greater kinetic energy, which may result in damage to the product. When there is rotation motion, product selection should be based not on the load mass of the load, but on the moment of inertia.

### Moment of inertia

The moment of inertia is a value indicating the inertia of a rotating body, and expresses the degree to which the body is difficult to rotate, or difficult to stop.

It is necessary to know the moment of inertia of the load in order to determine the value of necessary torque or kinetic energy when selecting a rotary actuator.

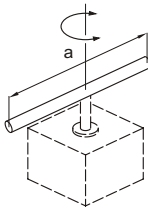


$I = m \cdot r^2$   
 $m$  : Mass  
 $r$  : Radius of rotation

This formula represents the moment of inertia for the shaft with mass  $m$ , which is located at distance  $r$  from the shaft. For actual loads, the values of the moment of inertia are calculated depending on configurations, as shown on the next page.

### 1. Thin shaft

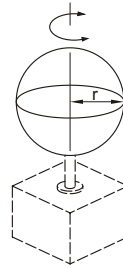
Position of rotational axis: Perpendicular to the shaft through the center of gravity.



$$I = m \cdot \frac{a^2}{12}$$

### 5. Solid sphere

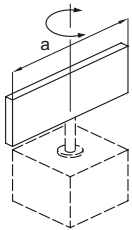
Position of rotational axis: Through the center of diameter.



$$I = m \cdot \frac{2r^2}{5}$$

### 2. Thin rectangular plate

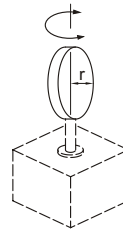
Position of rotational axis: Parallel to side b and through the center of gravity.



$$I = m \cdot \frac{a^2}{12}$$

### 6. Thin round plate

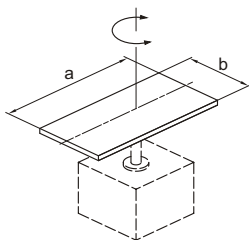
Position of rotational axis: Through the center of diameter.



$$I = m \cdot \frac{r^2}{2}$$

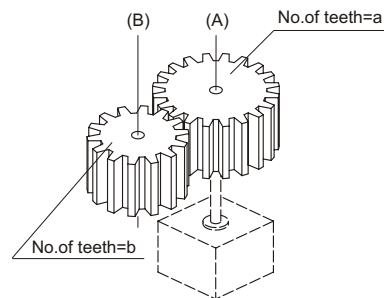
### 3. Thin rectangular plate (Including rectangular parallelepiped)

Position of rotational axis: Perpendicular to the plate through the center of gravity.



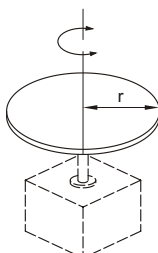
$$I = m \cdot \frac{a^2 + b^2}{12}$$

### 7. Gear transmission



### 4. Round plate (Including column)

Position of rotational axis: Through the center axis.



$$I = m \cdot \frac{r^2}{2}$$

1. Find the moment of inertia  $I_B$  for the rotation of shaft (B).
2.  $I_B$  is converted to the moment of inertia  $I_A$  for the rotation of the shaft (A).

$$I_A = \left(\frac{a}{b}\right)^2 \cdot I_B$$

To find the rotation time when kinetic energy is within the allowable range for the product, use the following formula.

$$t \cong \sqrt{\frac{2 \cdot I \cdot \theta^2}{E}}$$

t : Rotation time (s)  
 E : Kinetic energy (J)  
 I : Moment of inertia (kg.m<sup>2</sup>)  
 θ : Rotation angle (rad)

Use the following formula to calculate the kinetic energy of the load.

$$E = 1/2 \cdot I \cdot \omega^2$$

E : Kinetic energy (J)  
 I : Moment of inertia (kg.m<sup>2</sup>)  
 ω : Angle speed (rad/s)

Angle speed

$$\omega = 2\theta / t \dots (1)$$

$$\omega = \theta / t \dots (2)$$

t : Rotation time (s)  
 I : Moment of inertia (kg.m<sup>2</sup>)  
 θ : Rotation angle (rad)

However, when the rotation time for 90° becomes longer than 2 seconds, use formula (2).

### Calculation example:

Load form: Cuboid

Rotation angle θ : 180°

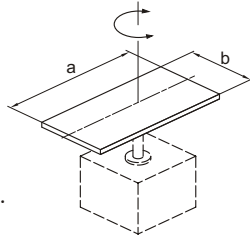
Rotation time t : 1 s/180°

Length of a part : 0.12 m

Length of b part : 0.06 m

Mass (m) : 0.1 kg

$$I = m \cdot \frac{a^2 + b^2}{12}$$



(Step 1) Find the angle speed ω.

$$\omega = \frac{2\theta}{t} = \frac{2}{1} \times \pi = 6.28 \text{ rad/s}$$

(Step 2) Find the moment of inertia I.

$$\begin{aligned}
 I &= m \cdot \frac{a^2 + b^2}{12} \\
 &= 0.1 \times \frac{144 \times 10^{-4} + 36 \times 10^{-4}}{12} \\
 &= 1.5 \times 10^{-4} \text{ kg.m}^2
 \end{aligned}$$

(Step 3) Find the kinetic energy E.

$$\begin{aligned}
 E &= \frac{1}{2} \cdot I \cdot \omega^2 = \frac{1}{2} \times 1.5 \times 10^{-4} \times 6.28^2 \\
 &= 0.002958 \text{ J}
 \end{aligned}$$