Calculating the Applied Load

The LM Guide is capable of receiving loads and moments in all directions whether they are generated by the mounting orientation and position, the location of the center of gravity of the moving object, the position of the thrust, the acceleration, or the cutting resistance.

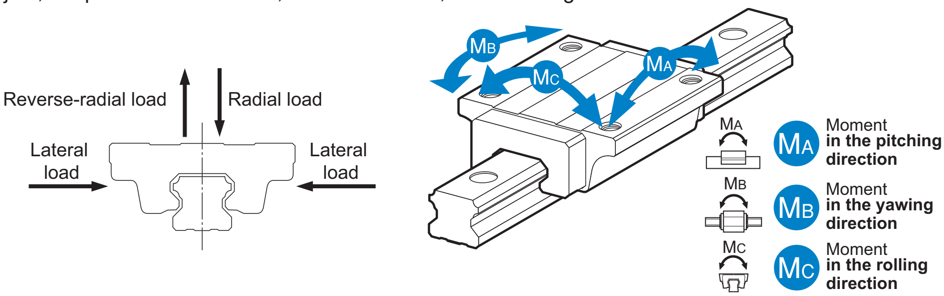


Fig. 1: Directions of the Loads Applied on the LM Guide

Calculating an Applied Load

Single-Axis Use

● **Moment Equivalence**

When the space to install the LM Guide is limited, you may have to use only one LM block, or two LM blocks in close contact with each other. In such a setting, the load distribution is not uniform. As a result, an excessive load is applied in localized areas (i.e., both ends) as shown in Fig. 2. Continued use under such conditions may result in flaking in those areas, consequently shortening the service life. In such a case, calculate the actual load by multiplying the moment value by any one of the equivalent-moment factors specified in Table 1 to Table 6 A**1-43**.

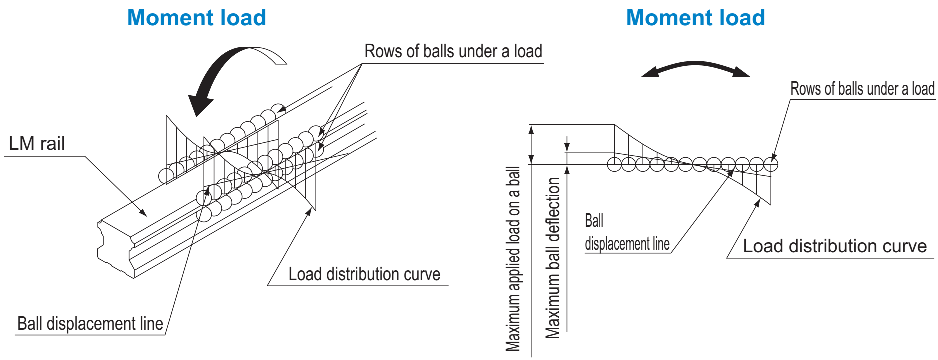


Fig. 2: Ball Load when a Moment is Applied

An equivalent-load equation applicable when a moment acts on an LM Guide is shown below.

$$P = K \cdot M$$

P : Equivalent load per LM Guide (N)
K : Equivalent moment factor
M : Applied moment (N·mm)

● Equivalent Factor

Since the rated load is equivalent to the permissible moment, the equivalent factor to be multiplied when equalizing the M_A, M_B, and M_C moments to the applied load per block is obtained by dividing the rated loads in the corresponding directions.
With models other than 4-way equal load types, however, the load ratings in the 4 directions differ from each other. Therefore, the equivalent factor values for the M_A and M_C moments also differ depending on whether the direction is radial or reverse radial.

■Equivalent Factors for the M_A Moment

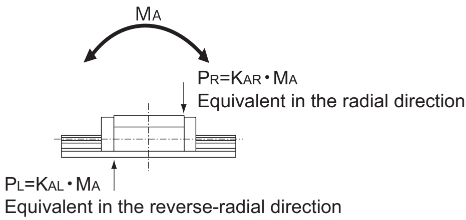


Fig. 3: Equivalent Factors for the M_A Moment

Equivalent factors for the M_A Moment

- Equivalent factor in the radial direction $K_{AR} = \dfrac{C_0}{M_A}$
- Equivalent factor in the reverse-radial direction $K_{AL} = \dfrac{C_{0L}}{M_A}$

$$\frac{C_0}{K_{AR} \cdot M_A} = \frac{C_{0L}}{K_{AL} \cdot M_A} = 1$$

■Equivalent Factors for the M_B Moment

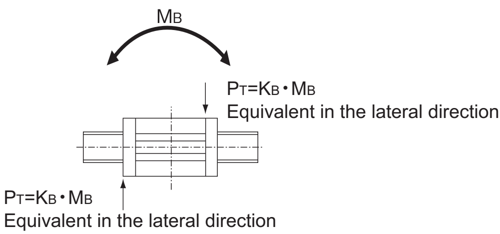


Fig. 4: Equivalent Factors for the M_B Moment

Equivalent factors for the M_B Moment

- Equivalent factor in the lateral directions $K_B = \dfrac{C_{0T}}{M_B}$

$$\frac{C_{0T}}{K_B \cdot M_B} = 1$$

■Equivalent Factors for the M_C Moment

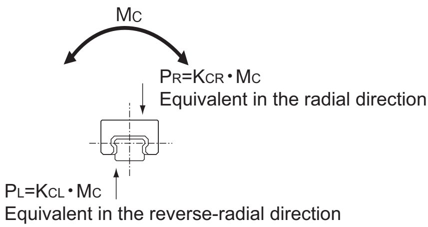


Fig. 5: Equivalent Factors for the M_C Moment

Equivalent factors for the M_C Moment

- Equivalent factor in the radial direction $K_{CR}=\frac{C_0}{M_C}$
- Equivalent factor in the reverse-radial direction $K_{CL}=\frac{C_{0L}}{M_C}$

$$\frac{C_0}{K_{CR}\cdot M_C}=\frac{C_{0L}}{K_{CL}\cdot M_C}=1$$

C_0 : Basic static load rating (radial direction) (N)
C_{0L} : Basic static load rating (reverse-radial direction) (N)
C_{0T} : Basic static load rating (lateral direction) (N)
P_R : Calculated load (radial direction) (N)
P_L : Calculated load (reverse-radial direction) (N)
P_T : Calculated load (lateral direction) (N)

Example Calculations

When One LM Block is Used

Model No.: SSR20XV1

Gravitational acceleration $g = 9.8$ (m/s^2)
Mass $m = 10$ (kg)
$\ell_1 = 200$ (mm)
$\ell_2 = 100$ (mm)

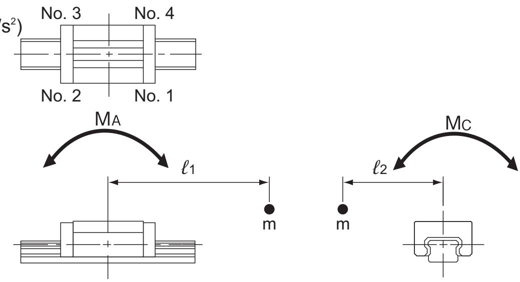


Fig. 6: When One LM Block is Used

No. 1 $P_1 = mg + K_{AR1}\cdot mg\cdot\ell_1 + K_{CR}\cdot mg\cdot\ell_2 = 98+0.275\times98\times200+0.129\times98\times100 = 6752$ (N)
No. 2 $P_2 = mg - K_{AL1}\cdot mg\cdot\ell_1 + K_{CR}\cdot mg\cdot\ell_2 = 98-0.137\times98\times200+0.129\times98\times100 = -1323$ (N)
No. 3 $P_3 = mg - K_{AL1}\cdot mg\cdot\ell_1 - K_{CL}\cdot mg\cdot\ell_2 = 98-0.137\times98\times200-0.0644\times98\times100 = -3218$ (N)
No. 4 $P_4 = mg + K_{AR1}\cdot mg\cdot\ell_1 - K_{CL}\cdot mg\cdot\ell_2 = 98+0.275\times98\times200-0.0644\times98\times100 = 4857$ (N)

When Two LM Blocks are Used in Close Contact with Each Other

Model No.: SVS25R2

Gravitational acceleration $g = 9.8$ (m/s^2)
Mass $m = 5$ (kg)
$\ell_1 = 200$ (mm)
$\ell_2 = 150$ (mm)

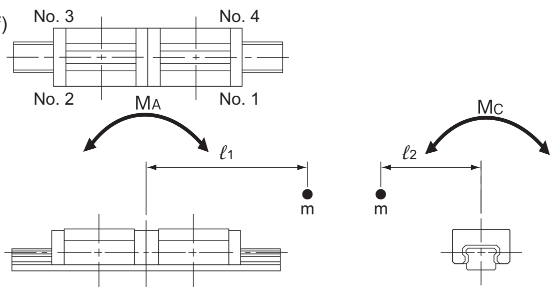


Fig. 7: When Two LM Blocks are Used in Close Contact with Each Other

No.1 $P_1 = \frac{mg}{2} + K_{AR2}\cdot mg\cdot\ell_1 + K_{CR}\cdot\frac{mg\cdot\ell_2}{2} = \frac{49}{2}+0.0217\times49\times200+0.0995\times\frac{49\times150}{2} = 602.9$ (N)

No.2 $P_2 = \frac{mg}{2} - K_{AL2}\cdot mg\cdot\ell_1 + K_{CR}\cdot\frac{mg\cdot\ell_2}{2} = \frac{49}{2}-0.0182\times49\times200+0.0995\times\frac{49\times150}{2} = 211.9$ (N)

No.3 $P_3 = \frac{mg}{2} - K_{AL2}\cdot mg\cdot\ell_1 - K_{CL}\cdot\frac{mg\cdot\ell_2}{2} = \frac{49}{2}-0.0182\times49\times200-0.0835\times\frac{49\times150}{2} = -460.7$ (N)

No.4 $P_4 = \frac{mg}{2} + K_{AR2}\cdot mg\cdot\ell_1 - K_{CL}\cdot\frac{mg\cdot\ell_2}{2} = \frac{49}{2}+0.0217\times49\times200-0.0835\times\frac{49\times150}{2} = -69.7$ (N)

Note1) Since an LM Guide used in vertical installation receives only a moment load, there is no need to apply a load force (mg).

Double-Axis Use

● Determining the Operating Conditions

Set the conditions needed to calculate the applied load and service life in hours for the LM System.

(1) Mass: m (kg)
(2) Direction of the working load
(3) Position of the working point (e.g., center of gravity): ℓ_2, ℓ_3, h_1 (mm)
(4) Thrust position: ℓ_4, h_2 (mm)
(5) LM system arrangement: ℓ_0, ℓ_1 (mm)
(No. of units and axes)
(6) Velocity diagram
Speed: V (mm/s)
Time constant: t_n (s)
Acceleration: α_n (mm/s^2)

$$\left(\alpha_n = \frac{V}{t_n}\right)$$

(7) Duty cycle
Number of reciprocations per minute: N_1 (min^{-1})
(8) Stroke length: ℓ_s (mm)
(9) Average speed: V_m (m/s)
(10) Required service life in hours: L_h (h)

Gravitational acceleration g = 9.8 (m/s^2)

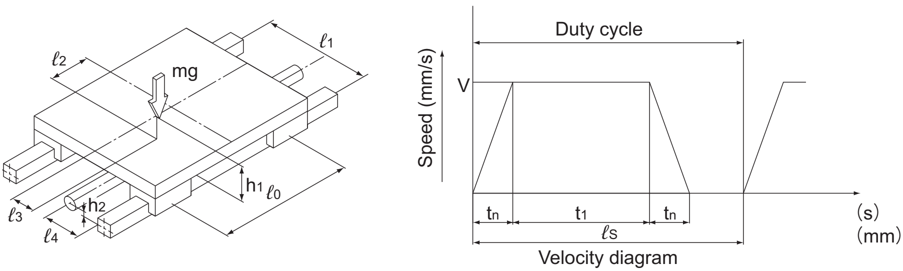


Fig. 8: Operating Conditions

● Applied Load Equation

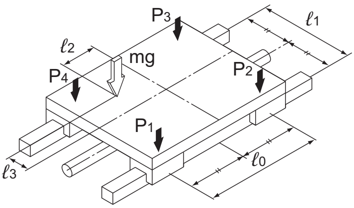
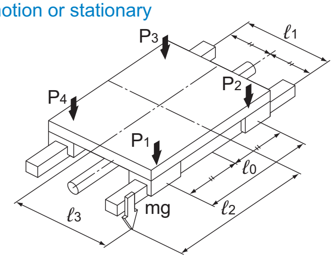
The load applied to the LM Guide varies with external forces such as the location of the center of gravity of the load, the position of the thrust, inertia generated by acceleration and deceleration during starts and stops, and cutting resistance.
In selecting an LM Guide, it is necessary to obtain the value of the applied load while taking into account these conditions.

Calculate the load applied to the LM Guide in each of the examples 1 to 10 shown below.

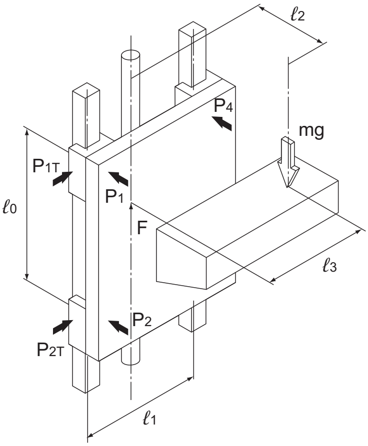
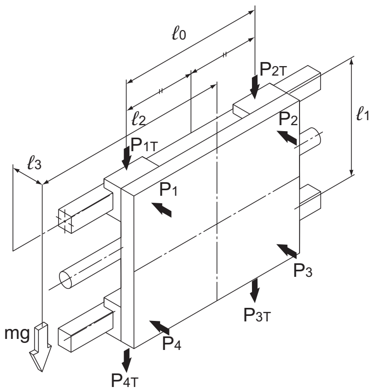
m	: Mass	(kg)
ℓ_n	: Distance	(mm)
F_n	: External force	(N)
P_n	: Applied load (radial/reverse-radial direction)	(N)
P_{nT}	: Applied load (lateral directions)	(N)
g	: Gravitational acceleration (g = 9.8 m/s²)	(m/s²)
V	: Speed	(m/s)
t_n	: Time constant	(s)
α_n	: Acceleration	(m/s²)

$$(\alpha_n = \frac{V}{t_n})$$

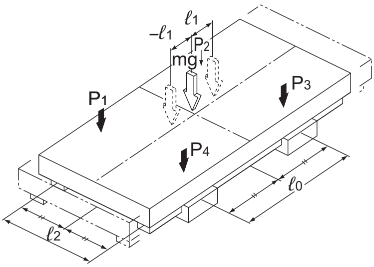
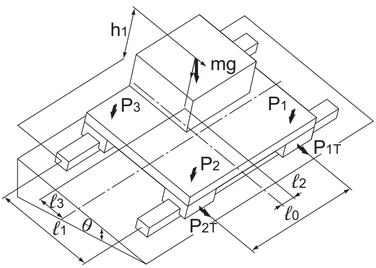
Example

	Operating conditions	Applied load equation
1	Horizontal mount (with the block moving) Uniform motion or stationary 	$P_1 = \frac{mg}{4} + \frac{mg\cdot\ell_2}{2\cdot\ell_0} - \frac{mg\cdot\ell_3}{2\cdot\ell_1}$ $P_2 = \frac{mg}{4} - \frac{mg\cdot\ell_2}{2\cdot\ell_0} - \frac{mg\cdot\ell_3}{2\cdot\ell_1}$ $P_3 = \frac{mg}{4} - \frac{mg\cdot\ell_2}{2\cdot\ell_0} + \frac{mg\cdot\ell_3}{2\cdot\ell_1}$ $P_4 = \frac{mg}{4} + \frac{mg\cdot\ell_2}{2\cdot\ell_0} + \frac{mg\cdot\ell_3}{2\cdot\ell_1}$
2	Horizontal mount, overhung (with the block moving) Uniform motion or stationary 	$P_1 = \frac{mg}{4} + \frac{mg\cdot\ell_2}{2\cdot\ell_0} + \frac{mg\cdot\ell_3}{2\cdot\ell_1}$ $P_2 = \frac{mg}{4} - \frac{mg\cdot\ell_2}{2\cdot\ell_0} + \frac{mg\cdot\ell_3}{2\cdot\ell_1}$ $P_3 = \frac{mg}{4} - \frac{mg\cdot\ell_2}{2\cdot\ell_0} - \frac{mg\cdot\ell_3}{2\cdot\ell_1}$ $P_4 = \frac{mg}{4} + \frac{mg\cdot\ell_2}{2\cdot\ell_0} - \frac{mg\cdot\ell_3}{2\cdot\ell_1}$

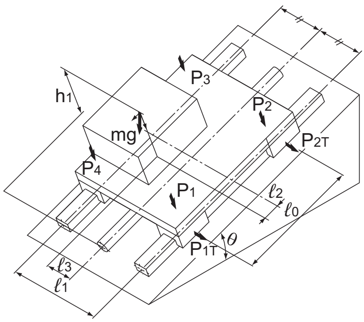
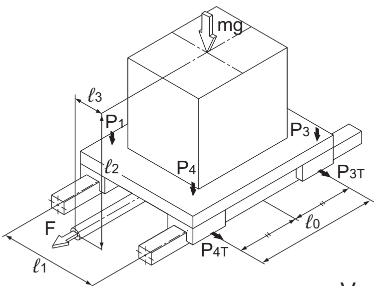
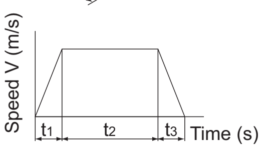
Note) Load is positive in the direction of the arrow.

	Operating conditions	Applied load equation
3	**Vertical mount** **Uniform motion or stationary**  E.g.: Vertical axis of industrial robot, automatic coating machine, lifter	$P_1 = P_4 = -\dfrac{mg \cdot \ell_2}{2 \cdot \ell_0}$ $P_2 = P_3 = \dfrac{mg \cdot \ell_2}{2 \cdot \ell_0}$ $P_{1T} = P_{4T} = \dfrac{mg \cdot \ell_3}{2 \cdot \ell_0}$ $P_{2T} = P_{3T} = -\dfrac{mg \cdot \ell_3}{2 \cdot \ell_0}$
4	**Wall mount** **Uniform motion or stationary**  E.g.: Travel axis of cross-rail loader	$P_1 = P_2 = -\dfrac{mg \cdot \ell_3}{2 \cdot \ell_1}$ $P_3 = P_4 = \dfrac{mg \cdot \ell_3}{2 \cdot \ell_1}$ $P_{1T} = P_{4T} = \dfrac{mg}{4} + \dfrac{mg \cdot \ell_2}{2 \cdot \ell_0}$ $P_{2T} = P_{3T} = \dfrac{mg}{4} - \dfrac{mg \cdot \ell_2}{2 \cdot \ell_0}$

Note) Load is positive in the direction of the arrow.

	Operating conditions	Applied load equation
5	**With the LM rails moving** **Horizontal mount**  E.g.: XY table sliding fork	$P_1 \text{ to } P_4\ (\max) = \frac{mg}{4} + \frac{mg \cdot \ell_1}{2 \cdot \ell_0}$ $P_1 \text{ to } P_4\ (\min) = \frac{mg}{4} - \frac{mg \cdot \ell_1}{2 \cdot \ell_0}$
6	**Lateral tilt mount**  E.g.: NC lathe carriage	$P_1 = +\frac{mg \cdot \cos\theta}{4} + \frac{mg \cdot \cos\theta \cdot \ell_2}{2 \cdot \ell_0} - \frac{mg \cdot \cos\theta \cdot \ell_3}{2 \cdot \ell_1} + \frac{mg \cdot \sin\theta \cdot h_1}{2 \cdot \ell_1}$ $P_{1T} = \frac{mg \cdot \sin\theta}{4} + \frac{mg \cdot \sin\theta \cdot \ell_2}{2 \cdot \ell_0}$ $P_2 = +\frac{mg \cdot \cos\theta}{4} - \frac{mg \cdot \cos\theta \cdot \ell_2}{2 \cdot \ell_0} - \frac{mg \cdot \cos\theta \cdot \ell_3}{2 \cdot \ell_1} + \frac{mg \cdot \sin\theta \cdot h_1}{2 \cdot \ell_1}$ $P_{2T} = \frac{mg \cdot \sin\theta}{4} - \frac{mg \cdot \sin\theta \cdot \ell_2}{2 \cdot \ell_0}$ $P_3 = +\frac{mg \cdot \cos\theta}{4} - \frac{mg \cdot \cos\theta \cdot \ell_2}{2 \cdot \ell_0} + \frac{mg \cdot \cos\theta \cdot \ell_3}{2 \cdot \ell_1} - \frac{mg \cdot \sin\theta \cdot h_1}{2 \cdot \ell_1}$ $P_{3T} = \frac{mg \cdot \sin\theta}{4} - \frac{mg \cdot \sin\theta \cdot \ell_2}{2 \cdot \ell_0}$ $P_4 = +\frac{mg \cdot \cos\theta}{4} + \frac{mg \cdot \cos\theta \cdot \ell_2}{2 \cdot \ell_0} + \frac{mg \cdot \cos\theta \cdot \ell_3}{2 \cdot \ell_1} - \frac{mg \cdot \sin\theta \cdot h_1}{2 \cdot \ell_1}$ $P_{4T} = \frac{mg \cdot \sin\theta}{4} + \frac{mg \cdot \sin\theta \cdot \ell_2}{2 \cdot \ell_0}$

Note) Load is positive in the direction of the arrow.

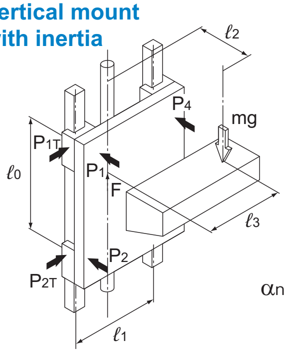
	Operating conditions	Applied load equation
7	**Longitudinal tilt mount**  E.g.: NC lathe tool rest	$P_1 = +\frac{mg\cdot\cos\theta}{4} + \frac{mg\cdot\cos\theta\cdot\ell_2}{2\cdot\ell_0} - \frac{mg\cdot\cos\theta\cdot\ell_3}{2\cdot\ell_1} + \frac{mg\cdot\sin\theta\cdot h_1}{2\cdot\ell_0}$ $P_{1T} = +\frac{mg\cdot\sin\theta\cdot\ell_3}{2\cdot\ell_0}$ $P_2 = +\frac{mg\cdot\cos\theta}{4} - \frac{mg\cdot\cos\theta\cdot\ell_2}{2\cdot\ell_0} - \frac{mg\cdot\cos\theta\cdot\ell_3}{2\cdot\ell_1} - \frac{mg\cdot\sin\theta\cdot h_1}{2\cdot\ell_0}$ $P_{2T} = -\frac{mg\cdot\sin\theta\cdot\ell_3}{2\cdot\ell_0}$ $P_3 = +\frac{mg\cdot\cos\theta}{4} - \frac{mg\cdot\cos\theta\cdot\ell_2}{2\cdot\ell_0} + \frac{mg\cdot\cos\theta\cdot\ell_3}{2\cdot\ell_1} - \frac{mg\cdot\sin\theta\cdot h_1}{2\cdot\ell_0}$ $P_{3T} = -\frac{mg\cdot\sin\theta\cdot\ell_3}{2\cdot\ell_0}$ $P_4 = +\frac{mg\cdot\cos\theta}{4} + \frac{mg\cdot\cos\theta\cdot\ell_2}{2\cdot\ell_0} + \frac{mg\cdot\cos\theta\cdot\ell_3}{2\cdot\ell_1} + \frac{mg\cdot\sin\theta\cdot h_1}{2\cdot\ell_0}$ $P_{4T} = +\frac{mg\cdot\sin\theta\cdot\ell_3}{2\cdot\ell_0}$
8	**Horizontal mount with inertia**   Velocity diagram $\alpha_n = \frac{V}{t_n}$ E.g.: Conveyance truck	During acceleration $P_1 = P_4 = \frac{mg}{4} - \frac{m\cdot\alpha_1\cdot\ell_2}{2\cdot\ell_0}$ $P_2 = P_3 = \frac{mg}{4} + \frac{m\cdot\alpha_1\cdot\ell_2}{2\cdot\ell_0}$ $P_{1T} = P_{4T} = \frac{m\cdot\alpha_1\cdot\ell_3}{2\cdot\ell_0}$ $P_{2T} = P_{3T} = -\frac{m\cdot\alpha_1\cdot\ell_3}{2\cdot\ell_0}$ During uniform motion P_1 to $P_4 = \frac{mg}{4}$ During deceleration $P_1 = P_4 = \frac{mg}{4} + \frac{m\cdot\alpha_3\cdot\ell_2}{2\cdot\ell_0}$ $P_2 = P_3 = \frac{mg}{4} - \frac{m\cdot\alpha_3\cdot\ell_2}{2\cdot\ell_0}$ $P_{1T} = P_{4T} = -\frac{m\cdot\alpha_3\cdot\ell_3}{2\cdot\ell_0}$ $P_{2T} = P_{3T} = \frac{m\cdot\alpha_3\cdot\ell_3}{2\cdot\ell_0}$

Note) Load is positive in the direction of the arrow.

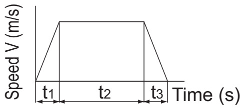
No.	Operating conditions	Applied load equation

9

Vertical mount with inertia



$$\alpha_n = \frac{V}{t_n}$$



Velocity diagram

E.g.: Conveyance lift

During acceleration

$$P_1 = P_4 = -\frac{m(g+\alpha_1)\ell_2}{2\cdot\ell_0}$$

$$P_2 = P_3 = \frac{m(g+\alpha_1)\ell_2}{2\cdot\ell_0}$$

$$P_{1T} = P_{4T} = \frac{m(g+\alpha_1)\ell_3}{2\cdot\ell_0}$$

$$P_{2T} = P_{3T} = -\frac{m(g+\alpha_1)\ell_3}{2\cdot\ell_0}$$

During uniform motion

$$P_1 = P_4 = -\frac{mg\cdot\ell_2}{2\cdot\ell_0}$$

$$P_2 = P_3 = \frac{mg\cdot\ell_2}{2\cdot\ell_0}$$

$$P_{1T} = P_{4T} = \frac{mg\cdot\ell_3}{2\cdot\ell_0}$$

$$P_{2T} = P_{3T} = -\frac{mg\cdot\ell_3}{2\cdot\ell_0}$$

During deceleration

$$P_1 = P_4 = -\frac{m(g-\alpha_3)\ell_2}{2\cdot\ell_0}$$

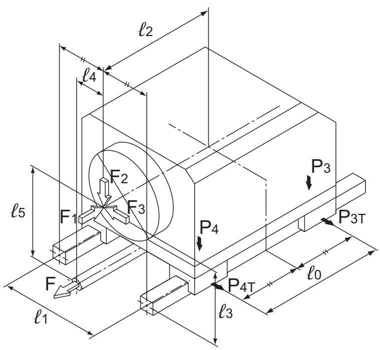
$$P_2 = P_3 = \frac{m(g-\alpha_3)\ell_2}{2\cdot\ell_0}$$

$$P_{1T} = P_{4T} = \frac{m(g-\alpha_3)\ell_3}{2\cdot\ell_0}$$

$$P_{2T} = P_{3T} = -\frac{m(g-\alpha_3)\ell_3}{2\cdot\ell_0}$$

10

Horizontal mount with external force



E.g.: Drill unit,
milling machine,
lathe,
machining center,
and other cutting machines

Under force F1

$$P_1 = P_4 = -\frac{F_1\cdot\ell_5}{2\cdot\ell_0}$$

$$P_2 = P_3 = \frac{F_1\cdot\ell_5}{2\cdot\ell_0}$$

$$P_{1T} = P_{4T} = \frac{F_1\cdot\ell_4}{2\cdot\ell_0}$$

$$P_{2T} = P_{3T} = -\frac{F_1\cdot\ell_4}{2\cdot\ell_0}$$

Under force F2

$$P_1 = P_4 = \frac{F_2}{4} + \frac{F_2\cdot\ell_2}{2\cdot\ell_0}$$

$$P_2 = P_3 = \frac{F_2}{4} - \frac{F_2\cdot\ell_2}{2\cdot\ell_0}$$

Under force F3

$$P_1 = P_2 = \frac{F_3\cdot\ell_3}{2\cdot\ell_1}$$

$$P_3 = P_4 = -\frac{F_3\cdot\ell_3}{2\cdot\ell_1}$$

$$P_{1T} = P_{4T} = -\frac{F_3}{4} - \frac{F_3\cdot\ell_2}{2\cdot\ell_0}$$

$$P_{2T} = P_{3T} = -\frac{F_3}{4} + \frac{F_3\cdot\ell_2}{2\cdot\ell_0}$$

Note) Load is positive in the direction of the arrow.