Calculating the Applied Load

The LM Guide is capable of receiving loads and moments in all directions that are generated due to the mounting orientation, alignment, gravity center position of a traveling object, thrust position and cutting resistance.

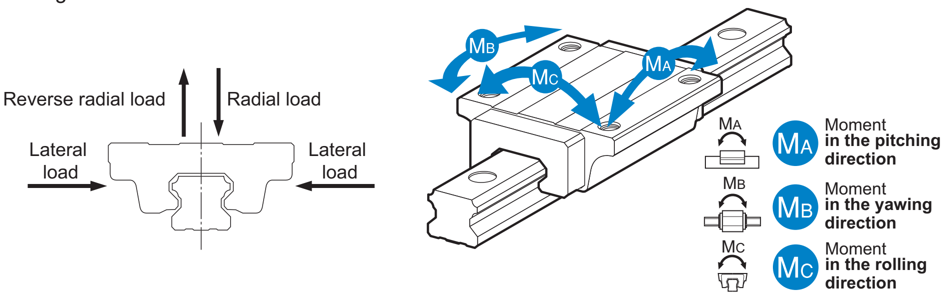


Fig.1 Directions of the Loads Applied on the LM Guide

Calculating an Applied Load

[Single-Axis Use]

● Moment Equivalence

When the installation space for the LM Guide is limited, you may have to use only one LM block, or double LM blocks closely contacting with each other. In such a setting, the load distribution is not uniform and, 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 Table1 to Table6 A1-43.

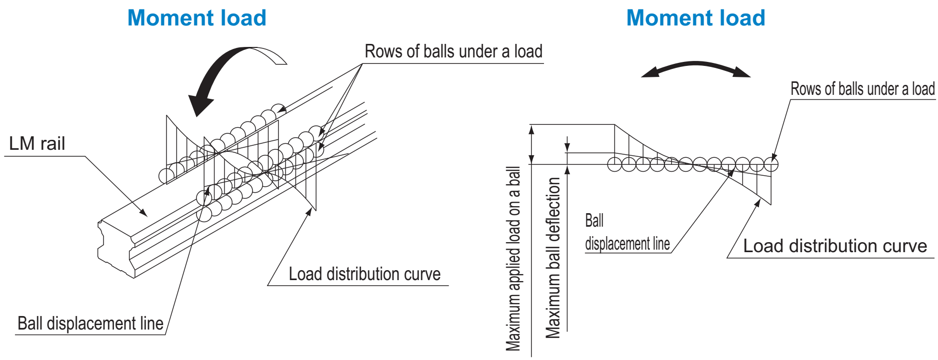


Fig.2 Ball Load when a Moment is Applied

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 those 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

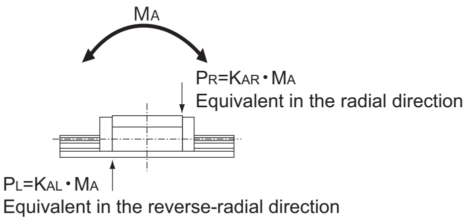


Fig.3 Equivalent Factors for the M_A Moment

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

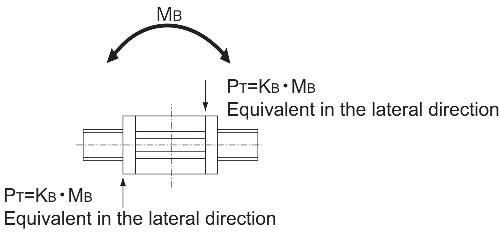


Fig.4 Equivalent Factors for the M_B Moment

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

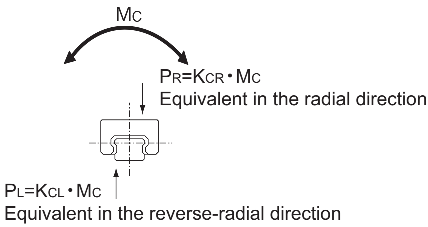


Fig.5 Equivalent Factors for the M_C Moment

Equivalent factors for the M_C Moment

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

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

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 of calculation

When one LM block is used

Model No.: SSR20XV1

Gravitational acceleration g=9.8 (m/s^2)
Mass m=10 (kg)
ℓ_1=200 (mm)
ℓ_2=100 (mm)

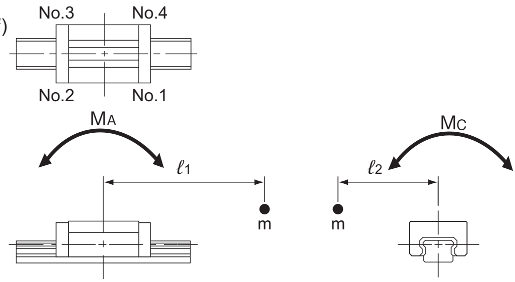


Fig.6 When One LM Block is Used

No.1 $P_1 = mg + K_{AR1} \cdot mg \cdot \ell_1 + K_{CR} \cdot mg \cdot \ell_2 = 98 + 0.275 \times 98 \times 200 + 0.129 \times 98 \times 100 = 6752$ (N)
No.2 $P_2 = mg - K_{AL1} \cdot mg \cdot \ell_1 + K_{CR} \cdot mg \cdot \ell_2 = 98 - 0.137 \times 98 \times 200 + 0.129 \times 98 \times 100 = -1323$ (N)
No.3 $P_3 = mg - K_{AL1} \cdot mg \cdot \ell_1 - K_{CL} \cdot mg \cdot \ell_2 = 98 - 0.137 \times 98 \times 200 - 0.0644 \times 98 \times 100 = -3218$ (N)
No.4 $P_4 = mg + K_{AR1} \cdot mg \cdot \ell_1 - K_{CL} \cdot mg \cdot \ell_2 = 98 + 0.275 \times 98 \times 200 - 0.0644 \times 98 \times 100 = 4857$ (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)
ℓ_1=200 (mm)
ℓ_2=150 (mm)

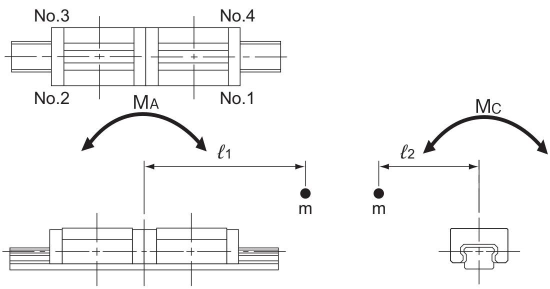


Fig.7 When Two LM Blocks are Used in Close Contact with Each Other

No.1 $P_1 = \frac{mg}{2} + K_{AR2} \cdot mg \cdot \ell_1 + K_{CR} \cdot \frac{mg \cdot \ell_2}{2} = \frac{49}{2} + 0.0217 \times 49 \times 200 + 0.0995 \times \frac{49 \times 150}{2} = 602.9$ (N)

No.2 $P_2 = \frac{mg}{2} - K_{AL2} \cdot mg \cdot \ell_1 + K_{CR} \cdot \frac{mg \cdot \ell_2}{2} = \frac{49}{2} - 0.0182 \times 49 \times 200 + 0.0995 \times \frac{49 \times 150}{2} = 211.9$ (N)

No.3 $P_3 = \frac{mg}{2} - K_{AL2} \cdot mg \cdot \ell_1 - K_{CL} \cdot \frac{mg \cdot \ell_2}{2} = \frac{49}{2} - 0.0182 \times 49 \times 200 - 0.0835 \times \frac{49 \times 150}{2} = -460.7$ (N)

No.4 $P_4 = \frac{mg}{2} + K_{AR2} \cdot mg \cdot \ell_1 - K_{CL} \cdot \frac{mg \cdot \ell_2}{2} = \frac{49}{2} + 0.0217 \times 49 \times 200 - 0.0835 \times \frac{49 \times 150}{2} = -69.7$ (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).

LM Guide

[Double-axis Use]

● Setting Conditions

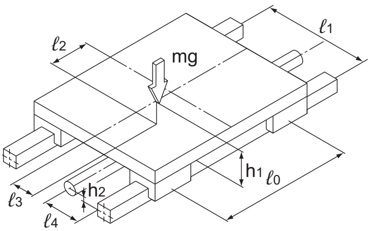
Set the conditions needed to calculate the LM system's applied load and service life in hours.
The conditions consist of the following items.

(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)



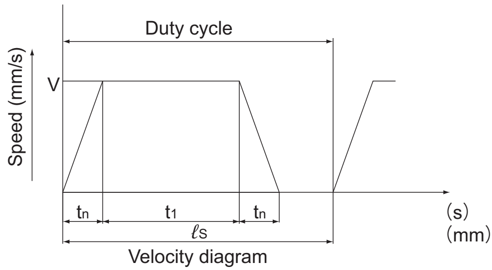


Fig.8 Condition

● Applied Load Equation

The load applied to the LM Guide varies with the external force, such as the position of the gravity center of an object, thrust position, inertia generated from acceleration/deceleration during start or stop, and cutting force.

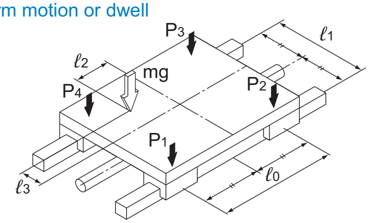
In selecting an LM Guide, it is necessary to obtain the value of the applied load while taking into account these conditions.

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 ($g = 9.8 m/s^2$)	(m/s^2)
V	:	Speed	(m/s)
t_n	:	Time constant	(s)
α_n	:	Acceleration	(m/s^2)

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

[Example]

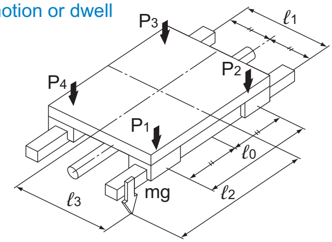
<table>
<tr><th></th><th>Condition</th><th>Applied Load Equation</th></tr>
<tr><td>1</td><td>Horizontal mount
(with the block traveling)
Uniform motion or dwell

</td><td>

$$P_1 = \frac{mg}{4} + \frac{mg \cdot \ell_2}{2 \cdot \ell_0} - \frac{mg \cdot \ell_3}{2 \cdot \ell_1}$$

$$P_2 = \frac{mg}{4} - \frac{mg \cdot \ell_2}{2 \cdot \ell_0} - \frac{mg \cdot \ell_3}{2 \cdot \ell_1}$$

$$P_3 = \frac{mg}{4} - \frac{mg \cdot \ell_2}{2 \cdot \ell_0} + \frac{mg \cdot \ell_3}{2 \cdot \ell_1}$$

$$P_4 = \frac{mg}{4} + \frac{mg \cdot \ell_2}{2 \cdot \ell_0} + \frac{mg \cdot \ell_3}{2 \cdot \ell_1}$$

</td></tr>
<tr><td>2</td><td>Horizontal mount, overhung
(with the block traveling)
Uniform motion or dwell

</td><td>

$$P_1 = \frac{mg}{4} + \frac{mg \cdot \ell_2}{2 \cdot \ell_0} + \frac{mg \cdot \ell_3}{2 \cdot \ell_1}$$

$$P_2 = \frac{mg}{4} - \frac{mg \cdot \ell_2}{2 \cdot \ell_0} + \frac{mg \cdot \ell_3}{2 \cdot \ell_1}$$

$$P_3 = \frac{mg}{4} - \frac{mg \cdot \ell_2}{2 \cdot \ell_0} - \frac{mg \cdot \ell_3}{2 \cdot \ell_1}$$

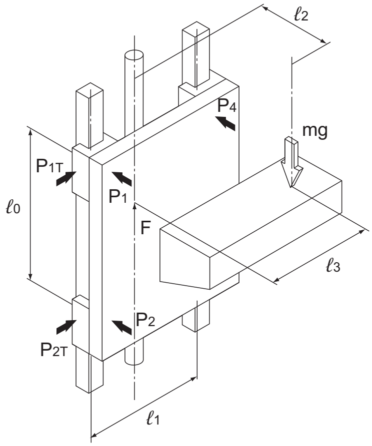
$$P_4 = \frac{mg}{4} + \frac{mg \cdot \ell_2}{2 \cdot \ell_0} - \frac{mg \cdot \ell_3}{2 \cdot \ell_1}$$

</td></tr>
</table>

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

<table>
<tr><th></th><th>Condition</th><th>Applied Load Equation</th></tr>
<tr><td>3</td><td>

Vertical mount
Uniform motion or dwell



E.g.: Vertical axis of industrial robot, automatic coating machine, lifter

</td><td>

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

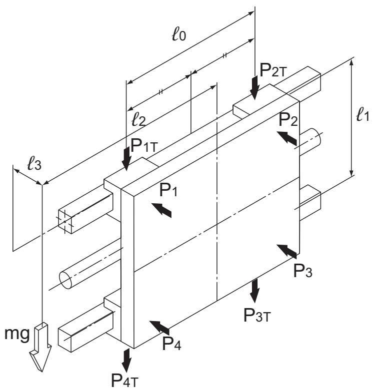
$$P_2 = P_3 = \frac{mg \cdot \ell_2}{2 \cdot \ell_0}$$

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

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

</td></tr>
<tr><td>4</td><td>

Wall mount
Uniform motion or dwell



E.g.: Travel axis of cross-rail loader

</td><td>

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

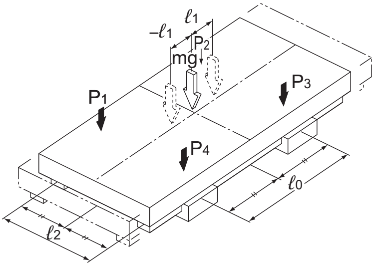
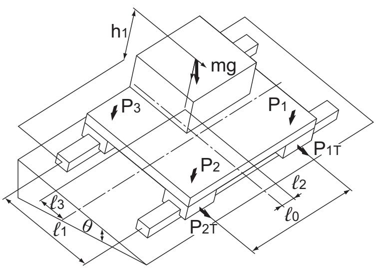
$$P_3 = P_4 = \frac{mg \cdot \ell_3}{2 \cdot \ell_1}$$

$$P_{1T} = P_{4T} = \frac{mg}{4} + \frac{mg \cdot \ell_2}{2 \cdot \ell_0}$$

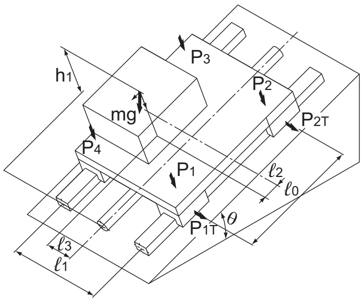
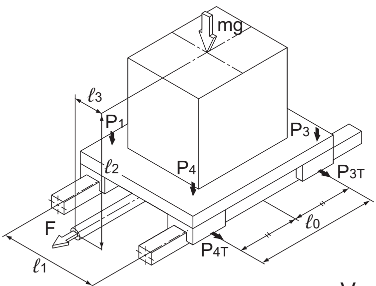
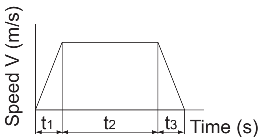
$$P_{2T} = P_{3T} = \frac{mg}{4} - \frac{mg \cdot \ell_2}{2 \cdot \ell_0}$$

</td></tr>
</table>

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

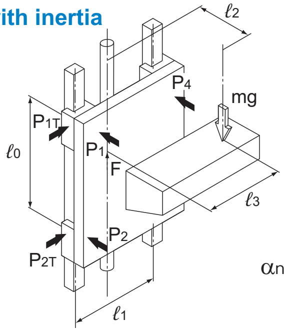
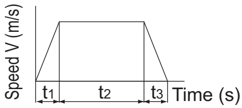
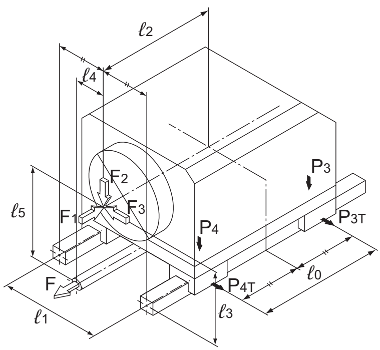
	Condition	Applied Load Equation
5	**With the LM rails movable** **Horizontal mount**  E.g.: XY table sliding fork	P_1 to P_4 (max) $= \dfrac{mg}{4} + \dfrac{mg \cdot \ell_1}{2 \cdot \ell_0}$ P_1 to P_4 (min) $= \dfrac{mg}{4} - \dfrac{mg \cdot \ell_1}{2 \cdot \ell_0}$
6	**Laterally tilt mount**  E.g.: NC lathe Carriage	$P_1 = +\dfrac{mg \cdot \cos\theta}{4} + \dfrac{mg \cdot \cos\theta \cdot \ell_2}{2 \cdot \ell_0} - \dfrac{mg \cdot \cos\theta \cdot \ell_3}{2 \cdot \ell_1} + \dfrac{mg \cdot \sin\theta \cdot h_1}{2 \cdot \ell_1}$ $P_{1T} = \dfrac{mg \cdot \sin\theta}{4} + \dfrac{mg \cdot \sin\theta \cdot \ell_2}{2 \cdot \ell_0}$ $P_2 = +\dfrac{mg \cdot \cos\theta}{4} - \dfrac{mg \cdot \cos\theta \cdot \ell_2}{2 \cdot \ell_0} - \dfrac{mg \cdot \cos\theta \cdot \ell_3}{2 \cdot \ell_1} + \dfrac{mg \cdot \sin\theta \cdot h_1}{2 \cdot \ell_1}$ $P_{2T} = \dfrac{mg \cdot \sin\theta}{4} - \dfrac{mg \cdot \sin\theta \cdot \ell_2}{2 \cdot \ell_0}$ $P_3 = +\dfrac{mg \cdot \cos\theta}{4} - \dfrac{mg \cdot \cos\theta \cdot \ell_2}{2 \cdot \ell_0} + \dfrac{mg \cdot \cos\theta \cdot \ell_3}{2 \cdot \ell_1} - \dfrac{mg \cdot \sin\theta \cdot h_1}{2 \cdot \ell_1}$ $P_{3T} = \dfrac{mg \cdot \sin\theta}{4} - \dfrac{mg \cdot \sin\theta \cdot \ell_2}{2 \cdot \ell_0}$ $P_4 = +\dfrac{mg \cdot \cos\theta}{4} + \dfrac{mg \cdot \cos\theta \cdot \ell_2}{2 \cdot \ell_0} + \dfrac{mg \cdot \cos\theta \cdot \ell_3}{2 \cdot \ell_1} - \dfrac{mg \cdot \sin\theta \cdot h_1}{2 \cdot \ell_1}$ $P_{4T} = \dfrac{mg \cdot \sin\theta}{4} + \dfrac{mg \cdot \sin\theta \cdot \ell_2}{2 \cdot \ell_0}$

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

	Condition	Applied Load Equation
7	**Longitudinally 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**  $\alpha_n = \frac{V}{t_n}$  Velocity diagram 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.

LM Guide

	Condition	Applied Load Equation
9	**Vertical mount with inertia**  $\alpha_n = \dfrac{V}{t_n}$  Velocity diagram E.g.: Conveyance lift	During acceleration $P_1 = P_4 = -\dfrac{m(g+\alpha_1)\ell_2}{2\cdot\ell_0}$ $P_2 = P_3 = \dfrac{m(g+\alpha_1)\ell_2}{2\cdot\ell_0}$ $P_{1T} = P_{4T} = \dfrac{m(g+\alpha_1)\ell_3}{2\cdot\ell_0}$ $P_{2T} = P_{3T} = -\dfrac{m(g+\alpha_1)\ell_3}{2\cdot\ell_0}$ During uniform motion $P_1 = P_4 = -\dfrac{mg\cdot\ell_2}{2\cdot\ell_0}$ $P_2 = P_3 = \dfrac{mg\cdot\ell_2}{2\cdot\ell_0}$ $P_{1T} = P_{4T} = \dfrac{mg\cdot\ell_3}{2\cdot\ell_0}$ $P_{2T} = P_{3T} = -\dfrac{mg\cdot\ell_3}{2\cdot\ell_0}$ During deceleration $P_1 = P_4 = -\dfrac{m(g-\alpha_3)\ell_2}{2\cdot\ell_0}$ $P_2 = P_3 = \dfrac{m(g-\alpha_3)\ell_2}{2\cdot\ell_0}$ $P_{1T} = P_{4T} = \dfrac{m(g-\alpha_3)\ell_3}{2\cdot\ell_0}$ $P_{2T} = P_{3T} = -\dfrac{m(g-\alpha_3)\ell_3}{2\cdot\ell_0}$
10	**Horizontal mount with external force**  E.g.: Drill unit, Milling machine, Lathe, Machining center and other cutting machine	Under force F1 $P_1 = P_4 = -\dfrac{F_1\cdot\ell_5}{2\cdot\ell_0}$ $P_2 = P_3 = \dfrac{F_1\cdot\ell_5}{2\cdot\ell_0}$ $P_{1T} = P_{4T} = \dfrac{F_1\cdot\ell_4}{2\cdot\ell_0}$ $P_{2T} = P_{3T} = -\dfrac{F_1\cdot\ell_4}{2\cdot\ell_0}$ Under force F2 $P_1 = P_4 = \dfrac{F_2}{4} + \dfrac{F_2\cdot\ell_2}{2\cdot\ell_0}$ $P_2 = P_3 = \dfrac{F_2}{4} - \dfrac{F_2\cdot\ell_2}{2\cdot\ell_0}$ Under force F3 $P_1 = P_2 = \dfrac{F_3\cdot\ell_3}{2\cdot\ell_1}$ $P_3 = P_4 = -\dfrac{F_3\cdot\ell_3}{2\cdot\ell_1}$ $P_{1T} = P_{4T} = -\dfrac{F_3}{4} - \dfrac{F_3\cdot\ell_2}{2\cdot\ell_0}$ $P_{2T} = P_{3T} = -\dfrac{F_3}{4} + \dfrac{F_3\cdot\ell_2}{2\cdot\ell_0}$

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