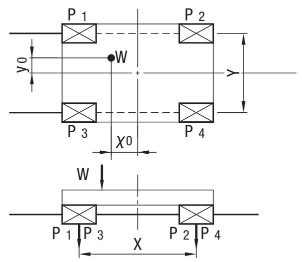
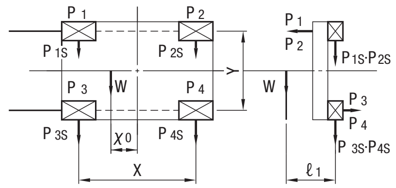
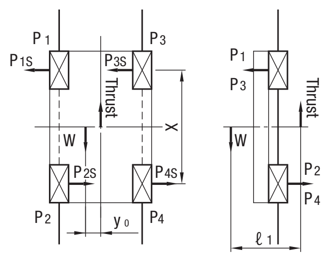
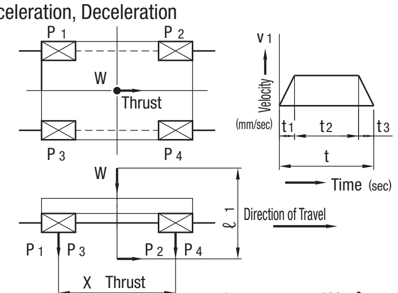
Calculation of Life Span of Linear Systems 2

•Load Calculations

Since a linear system bears the weight of the work while it performs a reciprocating linear motion, the load exerted on the system can vary depending on the work's center of gravity, thrust acting position change, and the speed changes by starting, stopping and acceleration, deceleration.

It is necessary to take these conditions into consideration when selecting a linear system.

Table-5. Use Conditions and Load Calculation Formulas

Type	Condition of Use and Load	Type	Condition of Use and Load
1	Horizontal Axis  $P_1=\frac{1}{4}W+\frac{x_0}{2X}W+\frac{y_0}{2Y}W$ $P_2=\frac{1}{4}W-\frac{x_0}{2X}W+\frac{y_0}{2Y}W$ $P_3=\frac{1}{4}W+\frac{x_0}{2X}W-\frac{y_0}{2Y}W$ $P_4=\frac{1}{4}W-\frac{x_0}{2X}W-\frac{y_0}{2Y}W$	3	Perpendicular to Horizontal Axis  $P_1=P_2=P_3=P_4=\frac{\ell_1}{2X}W$ $P_{1S}=P_{3S}=\frac{1}{4}W+\frac{x_0}{2X}W$ $P_{2S}=P_{4S}=\frac{1}{4}W-\frac{x_0}{2X}W$
2	Vertical Axis  $P_1=P_2=P_3=P_4=\frac{\ell_1}{2X}W$ $P_{1S}=P_{2S}=P_{3S}=P_{4S}=\frac{y_0}{2X}W$	4	In Acceleration, Deceleration  •Acceleration at Starting $P_1=P_3=\frac{1}{4}W\left(1+\frac{2V_1\cdot\ell_1}{g\cdot t_1\cdot X}\right)$ $P_2=P_4=\frac{1}{4}W\left(1-\frac{2V_1\cdot\ell_1}{g\cdot t_1\cdot X}\right)$ •Deceleration at Stopping $P_1=P_3=\frac{1}{4}W\left(1-\frac{2V_1\cdot\ell_1}{g\cdot t_3\cdot X}\right)$ $P_2=P_4=\frac{1}{4}W\left(1+\frac{2V_1\cdot\ell_1}{g\cdot t_3\cdot X}\right)$ •Constant Speed $P_1=P_2=P_3=P_4=\frac{1}{4}W$ g:Gravitational Acceleration=9.8×10^3mm/sec^2

W :Acting Load(N) P_1,P_2,P_3,P_4:Load applied to the Linear System(N)
X,Y: Linear System Span(mm) V:Moving Speed(mm/sec)
t_1 :Acceleration Time(sec) t_3:Deceleration Time(sec)

Fig-3. Stepped Load Fluctuation

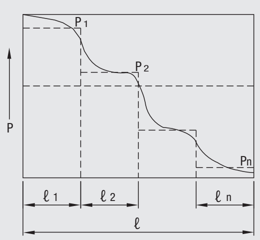


Fig-4. Flat Fluctuation Load

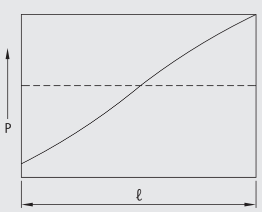
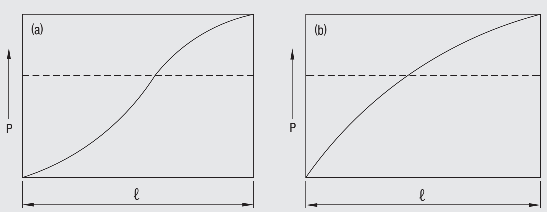


Fig-5. Sinusoidal Load Fluctuation



•Mean Load Derived from Fluctuating Loads

In general, the load acting upon a linear system can change according to how the system is used.This happens for example when the reciprocating motion is started, stopped as compared to constant speed motion, and whether or not work is present during transfer, etc. Therefore, in order to correctly design the life span under various conditions and fluctuating loads, it is necessary to obtain a mean load and apply it to the life span calculations.

(1) When load changes in steps by a travel distance(Fig-3)

Travel distance ℓ_1 subjected to load P_1
Travel distance ℓ_2 subjected to load P_2
⋮ ⋮
Travel distance ℓn subjected to load Pn

Mean load Pm can be obtained using the following formula:

$$P_m=\sqrt[3]{\frac{1}{\ell}(P_1{}^3\,\ell_1+P_2{}^3\,\ell_2\cdots+P_n{}^3\,\ell_n)}$$

P_m : Mean Load Derived from Fluctuating Loads(N) ℓ : Total Travel Distance(m)

(2) When load changes almost linearly(Fig-4)

Mean load P_m can be approximated by the following formula:

$$P_m\approx\frac{1}{3}(P_{min}+2\cdot P_{max})$$

P_{min} : Min. Fluctuating Load (N)
P_{max}: Max. Fluctuating Load(N)

(3) 3When the load change resembles a sinusoidal curve as shown in Fig-5 (a), (b), Mean Load Pm can be approximated by the following formula:

Fig-5(a)$P_m\approx0.65P_{max}$
Fig-5(b)$P_m\approx0.75P_{max}$

Slide Guides

Rated life span is the total travel distance each linear guide of the same series can endure under the same conditions, without the occurrence of flaking in 90% of the system.

Rated life span can be obtained as follows from the basic dynamic load rating and the load to the slide guide.

$$L=\left(\frac{f_T}{f_W}\cdot\frac{C}{P}\right)^3\cdot50 \qquad (1)$$

L : Rated Life Span(km) C : Basic dynamic load rating(N)
f_T : Temperature Coefficient(See Fig-2) P : Acting Load(N)
fw : Load Coefficient(See Fig-4)

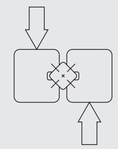
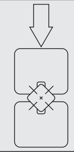
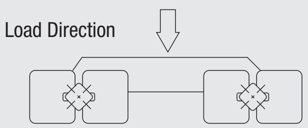
The life span hours can be computed as a number of hours by obtaining the travel distance for a unit of time.It can be obtained using the following formula, in which stroke length and stroke cycles are assumed to be constant.

$$L_h=\frac{L\cdot10^3}{2\cdot\ell_s\cdot n_1\cdot60} \qquad (2)$$

Lh : Life Span Hours(hr) ℓs : Stroke Length(m)
L : Rated Life Span(km) n_1 : Reciprocating Times per Minute(cpm)

Slide Ways

Rated load for slide ways is determined by the rolling elements(numbers of rollers). It can be calculated by using the following formulas:

One shaft is used	Load Direction	
	Dynamic Load Rating (N)	$C=\left(\frac{Z}{2}\right)^{3/4}\cdot C_1$
	Static Load Rating (N)	$C_0=\left(\frac{Z}{2}\right)\cdot C_{01}$
One shaft is used vertically	Load Direction	
	Dynamic Load Rating (N)	$C=\left(\frac{Z}{2}\right)^{3/4}\cdot C_1\cdot 2^{7/9}$
	Static Load Rating (N)	$C_0=\left(\frac{Z}{2}\right)\cdot C_{01}\cdot 2$
Two shafts are used in parallel	Load Direction	
	Dynamic Load Rating (N)	$C=\left(\frac{Z}{2}\right)^{3/4}\cdot C_1\cdot 2^{7/9}$
	Static Load Rating (N)	$C_0=\left(\frac{Z}{2}\right)\cdot C_{01}\cdot 2$

C_1 : Basic Dynamic Load Rating per Roller(N)
C_{01} : Basic Static Load Rating per Roller(N)
Z : Number or Rolling Elements

The life span for slide ways is calculated by using the following formula.

$$L=\left(\frac{f_T\cdot C}{f_W\cdot P}\right)^{10/3}\cdot50$$

L : Life Span Hours(km) C : Dynamic Load Rating(N)
f_T : Temperature Coefficient(See Fig-2) P : Acting Load(N)
fw : Load Coefficient(See Fig-4)

Life Span Hours

$$L_h=\frac{L\cdot10^3}{2\cdot\ell_s\cdot n_1\cdot60}$$

L_h : Life Span Hours(hr) ℓs: Stroke Length(m)
L : Life Span Hours(km) n_1: Reciprocating Times per Minute(cpm)