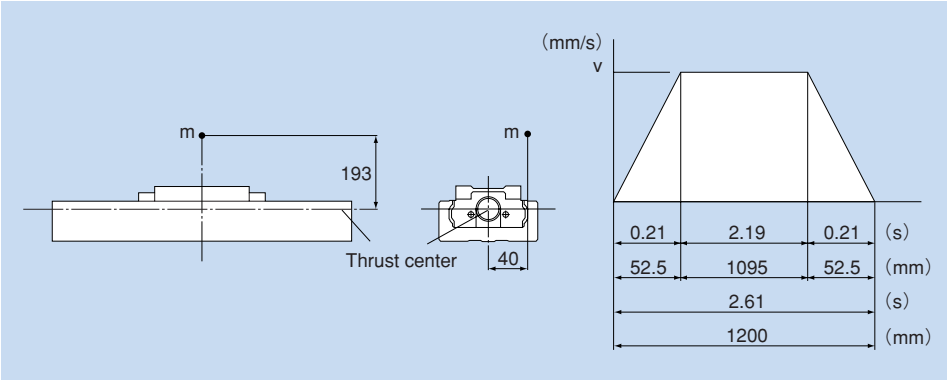
1.5. Example of Calculating the Rated Life

1.5.1. Service Conditions

Assumed model number:	KR5520A
LM Guide unit	(C=38100N, C_0=61900N)
Ball Screw unit	(C_a=3620N, C_{0a}=9290N)
Support bearing	(C_a=7600N, P_{0a}=3990N)
Mass:	m=30kg
Speed:	v=500mm/s
Acceleration:	α=2.4m/s^2
Stroke:	ℓ_s=1200mm
Gravitational acceleration:	g=9.807m/s^2
Speed diagram:	See the figure below.



1.5.2. Examination

Studying the LM Guide Unit

●Load applied to the nut block

* Assuming that a single nut block is used, convert applied moments M_A and M_B into applied load by multiplying them by the moment equivalent factor (K_A=K_B=8.63×10^{-2}).
* Assuming that a single shaft is used, convert applied moment M_C into applied load by multiplying it by the moment equivalent factor (K_C=2.83×10^{-2}).

■During even speed

$P_1 = mg + K_C \cdot mg \times 40 = 627$ N

■During acceleration

$P_{1a} = P_1 + K_A \cdot m\alpha \times 193 = 1826$ N

$P_{1aT} = -K_B \cdot m\alpha \times 40 = -249$ N

■During deceleration

$P_{1d} = P_1 - K_A \cdot m\alpha \times 193 = -572$ N

$P_{1dT} = K_B \cdot m\alpha \times 40 = 249$ N

* Since the groove under a load is different from the assumed groove, give "0" (zero) to P_{1sT} and P_{1d}.

●Resultant Load

■During even speed

$P_{1E} = P_1 = 627$ N

■During acceleration

$P_{1aE} = P_{1a} + P_{1aT} = 1826$ N

■During deceleration

$P_{1dE} = P_{1d} + P_{1dT} = 249$ N

●Static Safety Factor

$$f_s = \frac{C_0}{P_{max}} = \frac{C_0}{P_{1aE}} = 33.9$$

●Rated Life

■Average load

$$P_m = \sqrt[3]{\frac{1}{\ell_S}\left(P_{1E}^{\ 3} \times 1095 + P_{1aE}^{\ 3} \times 52.5 + P_{1dE}^{\ 3} \times 52.5\right)} = 790 \text{ N}$$

■Rated life

$$L = \left(\frac{C}{f_w \cdot P_m}\right)^3 \times 50 = 3.25 \times 10^6 \text{ km}$$

where

f_w : Load factor (1.2)

Studying the Ball Screw Unit

●Axial load

■During even-speed motion forward

$Fa_1 = \mu \cdot mg + f = 4$ N

μ : Friction coefficient (0.005)

f : Rolling resistance of one KR block + seal resistance (2.5 N)

■During forward acceleration

$Fa_2 = Fa_1 + m\alpha = 76$ N

■During forward deceleration

$Fa_3 = Fa_1 - m\alpha = -68$ N

■During even-speed motion backward

$Fa_4 = -Fa_1 = -4$ N

■During backward acceleration

$Fa_5 = Fa_4 - m\alpha = -76$ N

■During backward deceleration

$Fa_6 = Fa_4 + m\alpha = 68$ N

* Since the groove under a load is different from the assumed groove, give "0" (zero) to Fa_3, Fa_4 and Fa_5.

●Static safety factor

$$f_s = \frac{C_{0a}}{Fa_{max}} = \frac{C_{0a}}{Fa_2} = 122.2$$

●Buckling load

$$P_1 = \frac{n \cdot \pi^2 \cdot E \cdot I}{\ell_a^2} \times 0.5 = 11000 \text{ N}$$

where

P_1 : Buckling load (N)

ℓ_a : Center distance (1300 mm)

E : Young's modulus (2.06×10^5 N/mm^2)

n : Factor for mounting method (fixed - fixed: 4.0; see page K-43)

0.5 : Safety factor

I : Minimum geometrical moment of inertia of the screw shaft (mm^4)

$$I = \frac{\pi}{64} \cdot d_1^4$$

d_1 : Screw-shaft thread minor diameter (17.5 mm)

●Permissible tensile and compressive load

$$P_2 = \delta \cdot \frac{\pi}{4} \cdot d_1^2 = 35300 \text{ N}$$

where

P_2 : Permissible tensile and compressive load (N)
δ : Permissible tensile and compressive stress (147 N/mm²)
d_1 : Screw-shaft thread minor diameter (17.5 mm)

●Critical speed

$$N_1 = \frac{60 \cdot \lambda^2}{2\pi \cdot \ell_b^2} \cdot \sqrt{\frac{E \times 10^3 \cdot I}{\gamma \cdot A}} \times 0.8 = 1560 \text{ min}^{-1}$$

where

N_1 : Critical speed (min^{-1})
ℓ_b : Center distance (1300 mm)
γ : Density (7.85×10^{-6} kg/mm³)
λ : Factor for mounting method (fixed - supports: 3.927; see page K-45)
0.8 : Safety factor

●DN value

DN = 31125 (≦50000)

where

D : Ball center diameter (20.75 mm)
N : Maximum working rotation speed (1500 min^{-1})

●Rated life

■Average axial load

$$F_{am} = \sqrt[3]{\frac{1}{2 \cdot \ell_s}\left(F_{a1}^3 \times 1095 + F_{a2}^3 \times 52.5 + F_{a6}^3 \times 52.5\right)} = 25.5 \text{ N}$$

■Rated life

$$L = \left(\frac{C_a}{f_w \cdot F_{am}}\right)^3 \cdot \ell = 3.32 \times 10^7 \text{ km}$$

where

f_w : Load factor (1.2)
ℓ : Ball screw lead (20 mm)

Examining the Support Bearing Unit

●Axial load (same as the Ball Screw unit)

Fa_1 = 4 N
Fa_2 = 76 N
Fa_3 = 0 N
Fa_4 = 0 N
Fa_5 = 0 N
Fa_6 = 68 N

●Static safety factor

$$f_s = \frac{P_{0a}}{Fa_{max}} = \frac{P_{0a}}{Fa_2} = 52.5$$

●Rated life

■Average axial load

$$Fa_m = \sqrt[3]{\frac{1}{2 \cdot \ell_s}\left(Fa_1^{\,3} \times 1095 + Fa_2^{\,3} \times 52.5 + Fa_6^{\,3} \times 52.5\right)} = 25.5 \text{ N}$$

■Rated life

$$L = \left(\frac{Ca}{f_w \cdot Fa_m}\right)^3 \times 10^6 = 1.53 \times 10^{13} \text{ rev.}$$

where

f_w : Load factor (1.2)

* Convert the above rated life into the service life in travel distance of the Ball Screw.

$L_S = L \cdot \ell \times 10^{-6} = 3.06 \times 10^8$km

1.5.3. Result

The table below shows the result of the examination.

KR5520A	LM Guide unit	Ball Screw unit	Support bearing unit
Static safety factor	33.9	122.2	52.5
Buckling load (N)	—	11000	—
Permissible tensile-compressive load (N)	—	35300	—
Critical speed (min^{-1})	—	1560	—
DN value	—	31125	—
Rated life (km)	3.25×10^6	3.32×10^7	3.06×10^8
Maximum axial load (N)	—	76	—
Maximum working rotation speed (min^{-1})	—	1500	—

From the static safety coefficient and other values above, it is judged that the assumed model can be used. Of the rated lives of the three components, the shortest value (of LM Guide unit) is considered the rated life of the assumed model KR5520A.