Example of Calculating the Nominal Life

[Condition (Horizontal Installation)]

Assumed model number : KR 5520A
  LM Guide unit (C = 38100 N, C_0 = 61900 N)
  Ball Screw unit (C_a = 3620 N, C_{0a} = 9290 N)
  Bearing unit(Fixed Side) (C_a = 7600 N, P_{0a} = 3990 N)
Mass : m = 30 kg
Speed : v = 500 mm/s
Acceleration : α =2.4 m/s²
Stroke : ℓ_s = 1200 mm
Gravitational acceleration : g = 9.807 m/s²
Velocity diagram : see Fig.1

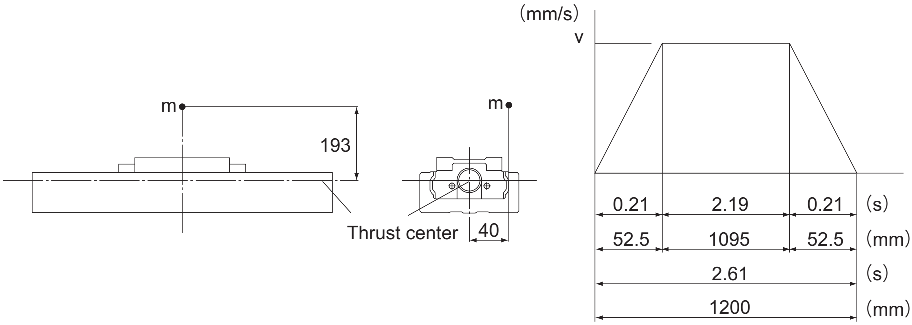


Fig.1 Velocity Diagram

[Consideration]

● **Studying the LM Guide Unit**

■Load Applied to the Inner Block

＊Assuming that a single inner block is used, convert applied moments M_A and M_B into applied load by multiplying them by the moment equivalent factor ($K_A = K_B = 8.63 \times 10^{-2}$).

＊Assuming that a single shaft is used, convert applied moment M_C into applied load by multiplying it by the moment equivalent factor ($K_C = 2.83 \times 10^{-2}$).

- During uniform motion:
  $P_1 = mg + K_C \cdot mg \times 40 = 627$ 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_{1aT} and P_{1d}.

■Combined Radial And Thrust Load

- During uniform motion:
  $P_{1E} = P_1 = 627$ N
- During acceleration:
  $P_{1aE} = P_{1a} + P_{1aT} = 1826$ N
- During deceleration:
  $P_{1dE} = P_{1d} + P_{1dT} = 249$ N

■Static Safety Factor

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

■Nominal Life

- Average load

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

- Nominal life

$$L_{10m} = \left(\alpha \times \frac{C}{P_m}\right)^3 \times 50 = 3.25 \times 10^6 \text{ km}$$

$$\alpha = \frac{1}{f_W}$$

f_W : Load factor (1.2)

● **Studying the Ball Screw Unit**

■Axial load

- During forward uniform motion:

$Fa_1 = \mu \cdot mg + f = 11$ N

μ : Friction coefficient(0.005)

f : Rolling resistance of one KR inner block + seal resistance(10.0 N)

- During forward acceleration:

$Fa_2 = Fa_1 + m\alpha = 83$ N

- During forward deceleration:

$Fa_3 = Fa_1 - m\alpha = -61$ N

- During uniform backward motion

$Fa_4 = -Fa_1 = -11$ N

- During backward acceleration:

$Fa_5 = Fa_4 - m\alpha = -83$ N

- During backward deceleration:

$Fa_6 = Fa_4 + m\alpha = 61$ 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

$$f_s = \frac{C_{0a}}{Fa_{max}} = \frac{C_{0a}}{Fa_2} = 111.9$$

■Buckling Load

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

P_1 : Buckling load (N)

ℓ_a : Distance between two mounting surfaces (1300 mm)

E : Young’s modulus (2.06×10^5 N/mm²)

n : Factor for mounting method (fixed-fixed: 4.0, see A15-30)

0.5 : Safety factor

I : Minimum geometrical moment of inertia of the shaft (mm⁴)

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

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

■Permissible tensile Compressive Load

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

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

■Dangerous Speed

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

N_1	: Dangerous speed	(min^{-1})
ℓ_b	: Distance between two mounting surfaces	(1300mm)
γ	: Density	(7.85×10^{-6}kg/mm³)
λ	: Factor according to the mounting method (fixed-supported 3.927, see **A15-32**)	
0.8	: Safety factor	

■DN Value

DN=31125(≦50000)

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

■Nominal Life

- Average axial load

$$F_{am} = \sqrt[3]{\frac{1}{2 \cdot \ell_S}(F_{a1}^{\,3} \times 1095 + F_{a2}^{\,3} \times 52.5 + F_{a6}^{\,3} \times 52.5)} = 26.2\ \mathrm{N}$$

- Nominal life

$$L_{10m} = \left(\frac{\alpha \cdot C_a}{F_{am}}\right)^3 \cdot \ell = 3.05 \times 10^7\ \mathrm{km}$$

$$\alpha = \frac{1}{f_W}$$

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

● **Bearing Unit (Fixed Side)**

■Axial Load (Same as the Ball Screw Unit)

Fa_1 = 11 N
Fa_2 = 83 N
Fa_3 = 0 N
Fa_4 = 0 N
Fa_5 = 0 N
Fa_6 = 61 N

■Static Safety Factor

$$f_s = \frac{P_{0a}}{Fa_{max}} = \frac{P_{0a}}{Fa_2} = 48.0$$

■Nominal Life

● Average axial load

$$Fa_m = \sqrt[3]{\frac{1}{2 \cdot \ell_s}(Fa_1{}^3 \times 1095 + Fa_2{}^3 \times 52.5 + Fa_6{}^3 \times 52.5)} = 26.2\ N$$

● Nominal life

$$L_{10m} = \left(\alpha \times \frac{C_a}{F_{am}}\right)^3 \times 10^6 = 1.41 \times 10^{13}\ rev$$

$$\alpha = \frac{1}{f_W}$$

f_W : Load factor (1.2)

∗Convert the above nominal life into the service life in travel distance of the Ball Screw.

$L_S = L_{10m} \cdot \ell \times 10^{-6} = 2.82 \times 10^8$ km

[Result]

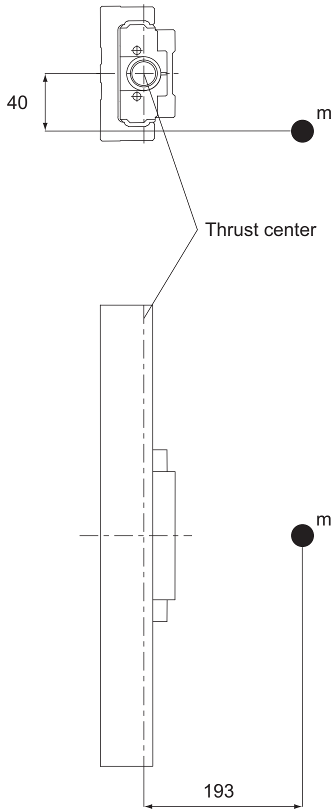
The table below shows the result of the examination.

KR5520A	LM guide unit	Ball screw unit	Bearing unit (Fixed side)
Static safety factor	33.9	111.9	48.0
Buckling load(N)	—	11000	—
Permissible tensile compressive load(N)	—	35300	—
Dangerous speed(min^{-1})	—	1560	—
DN Value	—	31125	—
Nominal life(km)	3.25×10^6	3.05×10^7	2.82×10^8
Maximum working rotation speed(min^{-1})	—	1500	—

Note1) From the static safety coefficient and other values above, it is judged that the assumed model can be used.
Note2) Of the rated lives of the three components, the shortest value (of LM Guide unit) is considered the nominal life of the assumed model KR 5520A.

[Condition (Vertical Installation)]

Assumed model number	: KR 5520A
LM Guide Unit	(C = 38100 N, C_0 = 61900 N)
Ball Screw Unit	(C_a = 3620 N, C_{0a} = 9290 N)
Bearing Unit(Fixed Side)	(C_a = 7600 N, P_{0a} = 3990 N)
Mass	: m = 30 kg
Speed	: v = 500 mm/s
Acceleration	: α =2.4 m/s^2
Stroke	: ℓ_s = 1200 mm
Gravitational acceleration	: g = 9.807 m/s^2
Velocity diagram	see Fig.2



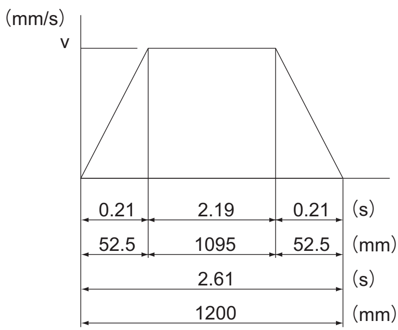


Fig.2 Velocity Diagram

[Consideration]

● **Studying the LM Guide Unit**

■Load Applied to the Inner Block

∗Assuming that a single inner block is used, convert applied moments M_A and M_B into applied load by multiplying them by the moment equivalent factor ($K_A = K_B = 8.63\times10^{-2}$).

- During uniform motion:
  $P_1 = K_A\cdot mg\times193 = 4900$ N
  $P_{1T} = K_B\cdot mg\times40 = 1016$ N
- During acceleration:
  $P_{1a} = P_1 + K_A\cdot m\alpha\times193 = 6100$ N
  $P_{1aT} = P_{1T} + K_B\cdot m\alpha\times40 = 1264$ N
- During deceleration:
  $P_{1d} = P_1 - K_A\cdot m\alpha\times193 = 3701$ N
  $P_{1dT} = P_{1d} - K_B\cdot m\alpha\times40 = 767$ N

■Combined Radial And Thrust Load

- During uniform motion:
  $P_{1E} = P_1 + P_{1T} = 5916$ N
- During acceleration:
  $P_{1aE} = P_{1a} + P_{1aT} = 7364$ N
- During deceleration:
  $P_{1dE} = P_{1d} + P_{1dT} = 4468$ N

■Static Safety Factor

$$f_s = \frac{C_0}{P_{max}} = \frac{C_0}{P_{1aE}} = 8.4$$

■Nominal Life

- Average load

$$P_m = \sqrt[3]{\frac{1}{\ell_S}\left(P_{1E}^3\times1095 + P_{1aE}^3\times52.5 + P_{1dE}^3\times52.5\right)} = 5947\ \text{N}$$

- Nominal life

$$L_{10m} = \left(\alpha\times\frac{C}{P_m}\right)^3\times50 = 7.61\times10^3\ \text{km}$$

$$\alpha = \frac{1}{f_W}$$

f_W : Load factor (1.2)

● Studying the Ball Screw Unit

■Axial Load

- During upward uniform motion:

  $Fa_1 = mg + f = 304$ N

  f : Sliding resistance per block (10.0 N)

- During upward acceleration:

  $Fa_2 = Fa_1 + m\alpha = 376$ N

- During upward deceleration:

  $Fa_3 = Fa_1 - m\alpha = 232$ N

- During downward uniform motion:

  $Fa_4 = mg - f = 284$ N

- During downward acceleration:

  $Fa_5 = Fa_4 - m\alpha = 212$ N

- During downward deceleration:

  $Fa_6 = Fa_4 + m\alpha = 356$ N

■Static Safety Factor

$$f_s = \frac{C_{0a}}{F_{max}} = \frac{C_{0a}}{Fa_2} = 24.7$$

■Buckling Load

Same as Horizontal Installation

■Permissible Tensile Compressive Load

Same as Horizontal Installation

■Dangerous Speed

Same as Horizontal Installation

■DN Value

Same as Horizontal Installation

■Nominal Life

- Average axial load

$$F_m = \sqrt[3]{\frac{1}{2 \cdot \ell_s}(Fa_1^3 \times 1095 + Fa_2^3 \times 52.5 + Fa_3^3 \times 52.5 + Fa_4^3 \times 1095 + Fa_5^3 \times 52.5 + Fa_6^3 \times 52.5)} = 296 \text{ N}$$

- Nominal life

$$L_{10m} = \left(\alpha \times \frac{C_a}{F_{am}}\right)^3 \times \ell = 2.11 \times 10^4 \text{ km}$$

$$\alpha = \frac{1}{f_w}$$

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

● **Bearing Unit (Fixed Side)**

■Axial Load (Same as the Ball Screw Unit)

Fa_1 = 304 N
Fa_2 = 376 N
Fa_3 = 232 N
Fa_4 = 284 N
Fa_5 = 212 N
Fa_6 = 356 N

■Static Safety Factor

$$f_s = \frac{P_{0a}}{F_{max}} = \frac{P_{0a}}{Fa_2} = 10.6$$

■Nominal Life

● Average axial load

$$F_m = \sqrt[3]{\frac{1}{2 \cdot \ell_S}(Fa_1^3 \times 1095 + Fa_2^3 \times 52.5 + Fa_3^3 \times 52.5 + Fa_4^3 \times 1095 + Fa_5^3 \times 52.5 + Fa_6^3 \times 52.5)} = 296 \text{ N}$$

● Nominal life

$$L_{10m} = \left(\alpha \times \frac{C_a}{F_{am}}\right)^3 \times \ell = 9.80 \times 10^9 \text{ rev}$$

$$\alpha = \frac{1}{f_W}$$

f_W : Load factor (1.2)

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

$L_S = L_{10m} \cdot \ell \times 10^{-6} = 1.95 \times 10^5$ km

[Result]

The table below shows the result of the examination.

KR5520A	LM guide unit	Ball screw unit	Bearing unit (Fixed side)
Static safety factor	8.4	24.7	10.6
Buckling load(N)	—	11000	—
Permissible tensile compressive load(N)	—	35300	—
Dangerous speed(min^{-1})	—	1560	—
DN Value	—	31125	—
Nominal life(km)	7.61×10^3	2.11×10^4	1.95×10^5
Maximum working rotation speed(min^{-1})	—	1500	—

Note1) From the static safety coefficient and other values above, it is judged that the assumed model can be used.
Note2) Of the rated lives of the three components, the shortest value (of LM Guide unit) is considered the nominal life of the assumed model KR 5520A.