Calculating the Nominal Life

The service life of an LM Guide is subject to variations even under the same operational conditions. Therefore, it is necessary to use the nominal life defined below as a reference value for obtaining the service life of the LM Guide. The nominal life means the total travel distance that 90% of a group of units of the same LM Guide model can achieve without flaking (scale-like pieces on the metal surface) after individually running under the same conditions.

Calculating the Nominal Life

The nominal life (L_{10}) of an LM Guide is obtained from the following formula using the basic dynamic load rating (C), which is based on a reference distance of 50 km for an LM Guide with balls and 100 km for an LM Guide with rollers, and the calculated load acting on the LM Guide (P_C).

●LM Guide with balls (using a basic dynamic load rating based on a nominal life of 50 km)

$$L_{10} = \left(\frac{C}{P_C}\right)^3 \times 50 \quad \cdots\cdots\cdots\cdots\cdots (1)$$

L_{10}	: Nominal life	(km)
C	: Basic dynamic load rating	(N)
P_C	: Calculated load	(N)

●LM Guide with rollers (using a basic dynamic load rating based on a nominal life of 100 km)

$$L_{10} = \left(\frac{C}{P_C}\right)^{\frac{10}{3}} \times 100 \quad \cdots\cdots\cdots\cdots (2)$$

∗These nominal life formulas may not apply if the length of the stroke is less than or equal to twice the length of the LM block.

When comparing the nominal life (L_{10}), you must take into account whether the basic dynamic load rating was defined based on 50 km or 100 km. Convert the basic dynamic load rating based on ISO 14728-1 as necessary.

ISO-regulated basic dynamic load rating conversion formulas:

- LM Guide with balls

$$C_{100} = \frac{C_{50}}{1.26}$$

C_{50} : Basic dynamic load rating based on a nominal life of 50 km

C_{100} : Basic dynamic load rating based on a nominal life of 100 km

- LM Guide with rollers

$$C_{100} = \frac{C_{50}}{1.23}$$

Calculating the Modified Nominal Life

During use, an LM Guide may be subjected to vibrations and shocks as well as fluctuating loads, which are difficult to detect. In addition, the surface hardness of the raceways, the operating temperature, and having LM blocks arranged directly behind one another will have a decisive impact on the service life. Taking these factors into account, the modified nominal life (L_{10m}) can be calculated according to the following formulas (3) and (4).

●Modified factor α

$$\alpha = \frac{f_H \cdot f_T \cdot f_C}{f_W}$$

α : Modified factor
f_H : Hardness factor
(see Fig. 10 on B1-75)
f_T : Temperature factor
(see Fig. 11 on B1-75)
f_C : Contact factor
(see Table 2 on B1-75)
f_W : Load factor
(see Table 3 on B1-76)

●Modified nominal life L_{10m}

- LM Guide with balls

$$L_{10m} = \left(\alpha \times \frac{C}{P_C}\right)^3 \times 50 \quad \cdots\cdots\cdots\cdots\cdots (3)$$

- LM Guide with rollers

$$L_{10m} = \left(\alpha \times \frac{C}{P_C}\right)^{\frac{10}{3}} \times 100 \quad \cdots\cdots\cdots\cdots (4)$$

L_{10m} : Modified nominal life (km)
C : Basic dynamic load rating (N)
P_C : Calculated load (N)

Once the nominal life (L_{10}) has been obtained, the service life time can be obtained using the following equation if the stroke length and the number of reciprocations are constant.

$$L_h = \frac{L_{10} \times 10^6}{2 \times \ell_s \times n_1 \times 60}$$

L_h : Service life time (h)
ℓ_s : Stroke length (mm)
n_1 : Number of reciprocations per minute (min^{-1})

f_H: Hardness Factor

To ensure that the LM Guide achieves optimum load capacity, the raceway hardness must be between 58 and 64 HRC.
If the hardness is lower than this range, the basic dynamic load rating and the basic static load rating decrease. Therefore, it is necessary to multiply each rating by the respective hardness factor (f_H).
Since the LM Guide has sufficient hardness, the f_H value for the LM Guide is normally 1.0 unless otherwise specified.

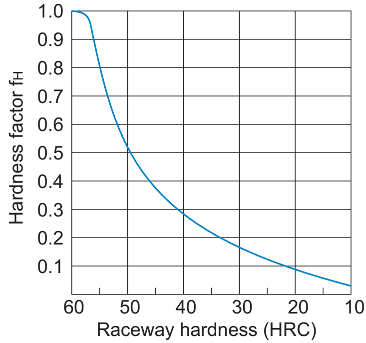


Fig. 10: Hardness Factor (f_H)

f_T: Temperature Factor

If the temperature of the operating environment surrounding the LM Guide exceeds 100℃, take into account the adverse effect of the high temperature and multiply the basic load ratings by the temperature factor indicated in Fig. 11.
In addition, the selected LM Guide must also be of a high-temperature type.

Note) An LM Guide not designed to withstand high temperatures should be used at 80°C or less. Please contact THK if application requirements exceed 80°C.

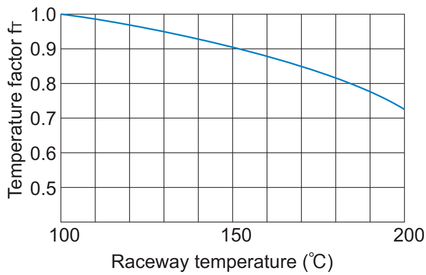


Fig. 11: Temperature Factor (f_T)

f_C: Contact Factor

When multiple LM blocks are used in close contact with each other, it is difficult to achieve uniform load distribution due to moment loads and mounting-surface accuracy. When using multiple blocks in close contact with each other, multiply the basic load rating (C or C_0) by the corresponding contact factor indicated in Table 2.

Note) If uneven load distribution is expected in a large machine, take into account the respective contact factor indicated in Table 2.

Table 2: Contact Factor (f_C)

Number of blocks used in close contact	Contact factor f_C
2	0.81
3	0.72
4	0.66
5	0.61
6 or greater	0.6
Normal use	1

f_W: Load Factor

In general, reciprocating machines tend to involve vibrations or impacts during operation. It is extremely difficult to accurately determine vibrations generated during high-speed operation and impacts that occur during frequent starts and stops. Therefore, where the effects of speed and vibration are estimated to be significant, divide the basic dynamic load rating (C) by a load factor selected from Table 3, which contains empirically obtained data.

Table 3: Load Factor (f_W)

Vibrations/ impacts	Speed (V)	f_W
Faint	Very low $V \leqq 0.25$ m/s	1 to 1.2
Weak	Low 0.25 m/s $< V \leqq 1$ m/s	1.2 to 1.5
Medium	Medium 1 m/s $< V \leqq 2$ m/s	1.5 to 2
Strong	High $V > 2$ m/s	2 to 3.5

Example of Calculating the Nominal Life (1) - with Horizontal Mount and High-Speed Acceleration

Conditions

Model No. : HSR35L
(basic dynamic load rating: C = 65.0 kN)
(basic static load rating: C_0 = 91.7 kN)

Mass : m_1 = 800 kg
m_2 = 500 kg

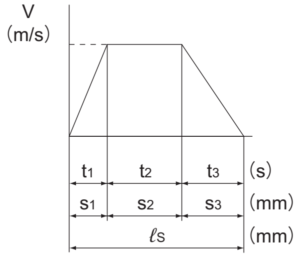
Speed : V = 0.5 m/s

Time : t_1 = 0.05 s
t_2 = 2.8 s
t_3 = 0.15 s

Acceleration : α_1 = 10 m/s^2
α_3 = 3.333 m/s^2

Stroke : ℓ_S = 1450 mm

Distance: ℓ_0 = 600 mm
ℓ_1 = 400 mm
ℓ_2 = 120 mm
ℓ_3 = 50 mm
ℓ_4 = 200 mm
ℓ_5 = 350 mm



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

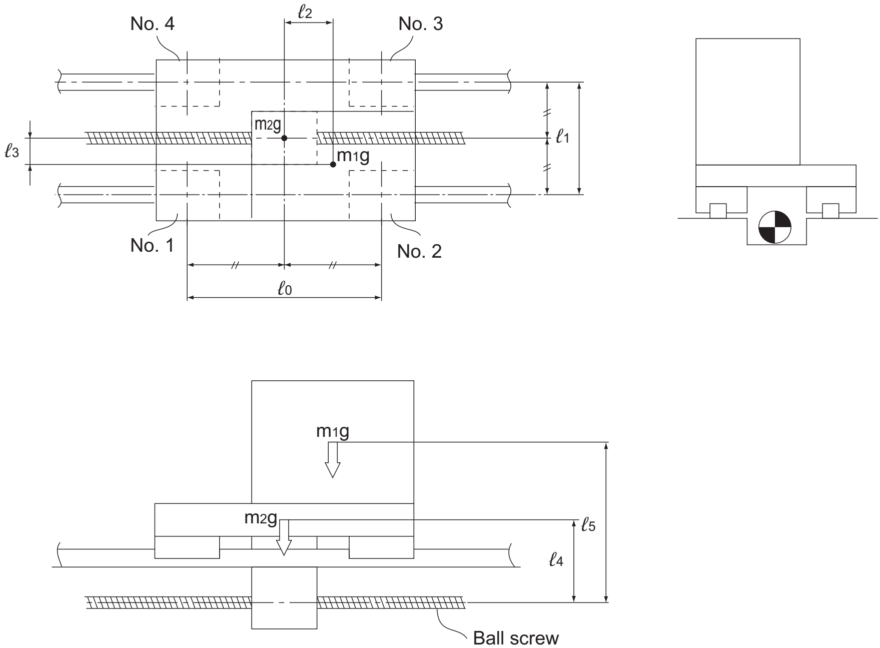


Fig. 12: Operating Conditions

Load Applied to the LM Block

Calculate the load applied to each LM block.

● During uniform motion

■Applied load in the radial direction P_n

$$P_1 = +\frac{m_1 g}{4} - \frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} + \frac{m_1 g \cdot \ell_3}{2 \cdot \ell_1} + \frac{m_2 g}{4} = +2891\ \text{N}$$

$$P_2 = +\frac{m_1 g}{4} + \frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} + \frac{m_1 g \cdot \ell_3}{2 \cdot \ell_1} + \frac{m_2 g}{4} = +4459\ \text{N}$$

$$P_3 = +\frac{m_1 g}{4} + \frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} - \frac{m_1 g \cdot \ell_3}{2 \cdot \ell_1} + \frac{m_2 g}{4} = +3479\ \text{N}$$

$$P_4 = +\frac{m_1 g}{4} - \frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} - \frac{m_1 g \cdot \ell_3}{2 \cdot \ell_1} + \frac{m_2 g}{4} = +1911\ \text{N}$$

● During leftward acceleration

■Applied load in the radial direction $P\ell a_n$

$$P\ell a_1 = P_1 - \frac{m_1 \cdot \alpha_1 \cdot \ell_5}{2 \cdot \ell_0} - \frac{m_2 \cdot \alpha_1 \cdot \ell_4}{2 \cdot \ell_0} = -\ 275.6\ \text{N}$$

$$P\ell a_2 = P_2 + \frac{m_1 \cdot \alpha_1 \cdot \ell_5}{2 \cdot \ell_0} + \frac{m_2 \cdot \alpha_1 \cdot \ell_4}{2 \cdot \ell_0} = +\ 7625.6\ \text{N}$$

$$P\ell a_3 = P_3 + \frac{m_1 \cdot \alpha_1 \cdot \ell_5}{2 \cdot \ell_0} + \frac{m_2 \cdot \alpha_1 \cdot \ell_4}{2 \cdot \ell_0} = +\ 6645.6\ \text{N}$$

$$P\ell a_4 = P_4 - \frac{m_1 \cdot \alpha_1 \cdot \ell_5}{2 \cdot \ell_0} - \frac{m_2 \cdot \alpha_1 \cdot \ell_4}{2 \cdot \ell_0} = -\ 1255.6\ \text{N}$$

■Applied load in the lateral direction $Pt\ell a_n$

$$Pt\ell a_1 = -\frac{m_1 \cdot \alpha_1 \cdot \ell_3}{2 \cdot \ell_0} = -\ 333.3\ \text{N}$$

$$Pt\ell a_2 = +\frac{m_1 \cdot \alpha_1 \cdot \ell_3}{2 \cdot \ell_0} = +\ 333.3\ \text{N}$$

$$Pt\ell a_3 = +\frac{m_1 \cdot \alpha_1 \cdot \ell_3}{2 \cdot \ell_0} = +\ 333.3\ \text{N}$$

$$Pt\ell a_4 = -\frac{m_1 \cdot \alpha_1 \cdot \ell_3}{2 \cdot \ell_0} = -\ 333.3\ \text{N}$$

● During leftward deceleration

■Applied load in the radial direction $P\ell d_n$

$$P\ell d_1 = P_1 + \frac{m_1 \cdot \alpha_3 \cdot \ell_5}{2 \cdot \ell_0} + \frac{m_2 \cdot \alpha_3 \cdot \ell_4}{2 \cdot \ell_0} = +\ 3946.6\ \text{N}$$

$$P\ell d_2 = P_2 - \frac{m_1 \cdot \alpha_3 \cdot \ell_5}{2 \cdot \ell_0} - \frac{m_2 \cdot \alpha_3 \cdot \ell_4}{2 \cdot \ell_0} = +\ 3403.4\ \text{N}$$

$$P\ell d_3 = P_3 - \frac{m_1 \cdot \alpha_3 \cdot \ell_5}{2 \cdot \ell_0} - \frac{m_2 \cdot \alpha_3 \cdot \ell_4}{2 \cdot \ell_0} = +\ 2423.4\ \text{N}$$

$$P\ell d_4 = P_4 + \frac{m_1 \cdot \alpha_3 \cdot \ell_5}{2 \cdot \ell_0} + \frac{m_2 \cdot \alpha_3 \cdot \ell_4}{2 \cdot \ell_0} = +\ 2966.6\ \text{N}$$

■Applied load in the lateral direction $Pt\ell d_n$

$$Pt\ell d_1 = + \frac{m_1 \cdot \alpha_3 \cdot \ell_3}{2 \cdot \ell_0} = +111.1\ N$$

$$Pt\ell d_2 = - \frac{m_1 \cdot \alpha_3 \cdot \ell_3}{2 \cdot \ell_0} = -111.1\ N$$

$$Pt\ell d_3 = - \frac{m_1 \cdot \alpha_3 \cdot \ell_3}{2 \cdot \ell_0} = -111.1\ N$$

$$Pt\ell d_4 = + \frac{m_1 \cdot \alpha_3 \cdot \ell_3}{2 \cdot \ell_0} = +111.1\ N$$

● **During rightward acceleration**

■Applied load in the radial direction Pra_n

$$Pra_1 = P_1 + \frac{m_1 \cdot \alpha_1 \cdot \ell_5}{2 \cdot \ell_0} + \frac{m_2 \cdot \alpha_1 \cdot \ell_4}{2 \cdot \ell_0} = +6057.6\ N$$

$$Pra_2 = P_2 - \frac{m_1 \cdot \alpha_1 \cdot \ell_5}{2 \cdot \ell_0} - \frac{m_2 \cdot \alpha_1 \cdot \ell_4}{2 \cdot \ell_0} = +1292.4\ N$$

$$Pra_3 = P_3 - \frac{m_1 \cdot \alpha_1 \cdot \ell_5}{2 \cdot \ell_0} - \frac{m_2 \cdot \alpha_1 \cdot \ell_4}{2 \cdot \ell_0} = +312.4\ N$$

$$Pra_4 = P_4 + \frac{m_1 \cdot \alpha_1 \cdot \ell_5}{2 \cdot \ell_0} + \frac{m_2 \cdot \alpha_1 \cdot \ell_4}{2 \cdot \ell_0} = +5077.6\ N$$

■Applied load in the lateral direction $Ptra_n$

$$Ptra_1 = + \frac{m_1 \cdot \alpha_1 \cdot \ell_3}{2 \cdot \ell_0} = +333.3\ N$$

$$Ptra_2 = - \frac{m_1 \cdot \alpha_1 \cdot \ell_3}{2 \cdot \ell_0} = -333.3\ N$$

$$Ptra_3 = - \frac{m_1 \cdot \alpha_1 \cdot \ell_3}{2 \cdot \ell_0} = -333.3\ N$$

$$Ptra_4 = + \frac{m_1 \cdot \alpha_1 \cdot \ell_3}{2 \cdot \ell_0} = +333.3\ N$$

● **During rightward deceleration**

■Applied load in the radial direction Prd_n

$$Prd_1 = P_1 - \frac{m_1 \cdot \alpha_3 \cdot \ell_5}{2 \cdot \ell_0} - \frac{m_2 \cdot \alpha_3 \cdot \ell_4}{2 \cdot \ell_0} = +1835.4\ N$$

$$Prd_2 = P_2 + \frac{m_1 \cdot \alpha_3 \cdot \ell_5}{2 \cdot \ell_0} + \frac{m_2 \cdot \alpha_3 \cdot \ell_4}{2 \cdot \ell_0} = +5514.6\ N$$

$$Prd_3 = P_3 + \frac{m_1 \cdot \alpha_3 \cdot \ell_5}{2 \cdot \ell_0} + \frac{m_2 \cdot \alpha_3 \cdot \ell_4}{2 \cdot \ell_0} = +4534.6\ N$$

$$Prd_4 = P_4 - \frac{m_1 \cdot \alpha_3 \cdot \ell_5}{2 \cdot \ell_0} - \frac{m_2 \cdot \alpha_3 \cdot \ell_4}{2 \cdot \ell_0} = +855.4\ N$$

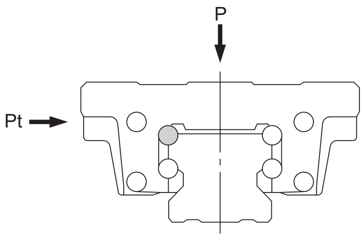
■Applied load in the lateral direction $Ptrd_n$

$$Ptrd_1 = -\frac{m_1 \cdot \alpha_3 \cdot \ell_3}{2 \cdot \ell_0} = -111.1\ N$$

$$Ptrd_2 = +\frac{m_1 \cdot \alpha_3 \cdot \ell_3}{2 \cdot \ell_0} = +111.1\ N$$

$$Ptrd_3 = +\frac{m_1 \cdot \alpha_3 \cdot \ell_3}{2 \cdot \ell_0} = +111.1\ N$$

$$Ptrd_4 = -\frac{m_1 \cdot \alpha_3 \cdot \ell_3}{2 \cdot \ell_0} = -111.1\ N$$



Combined Radial and Thrust Load

The combined radial and thrust load is calculated for each block only on the groove where the load is greatest.

Under these operating conditions, for each block, the groove for which the load is greatest is groove 1.*1

Because groove 1 bears P*2>0 and Pt>0 loads, it is 0 N when P<0 and Pt<0 loads are applied.

When calculating for the groove that will bear P<0 and Pt<0 loads, use the absolute value of the load.

*1 The reason that groove 1 has the greatest load is that mass m_1 is applied unevenly to the table and is not distributed equally to all grooves in the block.

*2 P refers to the radial load that each groove bears.

● During uniform motion

$P_{E1} = P_1 = 2891\ N$

$P_{E2} = P_2 = 4459\ N$

$P_{E3} = P_3 = 3479\ N$

$P_{E4} = P_4 = 1911\ N$

● During leftward acceleration

$P_E\ell a_1 = |P\ell a_1| + |Pt\ell a_1| = 0\ N$

$P_E\ell a_2 = |P\ell a_2| + |Pt\ell a_2| = 7958.9\ N$

$P_E\ell a_3 = |P\ell a_3| + |Pt\ell a_3| = 6978.9\ N$

$P_E\ell a_4 = |P\ell a_4| + |Pt\ell a_4| = 0\ N$

$P\ell a_1$, $Pt\ell a_1$, $P\ell a_4$, and $Pt\ell a_4 = 0\ N$

● During leftward deceleration

$P_E\ell d_1 = |P\ell d_1| + |Pt\ell d_1| = 4057.7\ N$

$P_E\ell d_2 = |P\ell d_2| + |Pt\ell d_2| = 3403.4\ N$

$P_E\ell d_3 = |P\ell d_3| + |Pt\ell d_3| = 2423.4\ N$

$P_E\ell d_4 = |P\ell d_4| + |Pt\ell d_4| = 3077.7\ N$

$Pt\ell d_2$ and $Pt\ell d_3 = 0\ N$

● During rightward acceleration

$P_Era_1 = |Pra_1| + |Ptra_1| = 6390.9\ N$

$P_Era_2 = |Pra_2| + |Ptra_2| = 1292.4\ N$

$P_Era_3 = |Pra_3| + |Ptra_3| = 312.4\ N$

$P_Era_4 = |Pra_4| + |Ptra_4| = 5410.9\ N$

$Ptra_2$ and $Ptra_3 = 0\ N$

● During rightward deceleration

$P_Erd_1 = |Prd_1| + |Ptrd_1| = 1835.4\ N$

$P_Erd_2 = |Prd_2| + |Ptrd_2| = 5625.7\ N$

$P_Erd_3 = |Prd_3| + |Ptrd_3| = 4645.7\ N$

$P_Erd_4 = |Prd_4| + |Ptrd_4| = 855.4\ N$

$Ptrd_1$ and $Ptrd_4 = 0\ N$

Static Safety Factor

As indicated above, the maximum load is applied to the LM Guide during the leftward acceleration of the second LM block. Therefore, the static safety factor (f_S) is obtained by the following equation.

$$f_S = \frac{C_0}{P_E\ell a_2} = \frac{91.7\times10^3}{7958.9} = 11.5$$

Average Load P_{mn}

Obtain the average load applied to each LM block.

$$P_{m1} = \sqrt[3]{\frac{1}{2\cdot\ell_S}\left(P_{E\ell a1}^3\cdot S_1 + P_{E1}^3\cdot S_2 + P_{E\ell d1}^3\cdot S_3 + P_{Era1}^3\cdot S_1 + P_{E1}^3\cdot S_2 + P_{Erd1}^3\cdot S_3\right)}$$

$$= \sqrt[3]{\frac{1}{2\times1450}\left(0\times12.5+2891^3\times1400+4057.7^3\times37.5+6390.9^3\times12.5+2891^3\times1400+1835.4^3\times37.5\right)}$$

$$= 2939.5\ \text{N}$$

$$P_{m2} = \sqrt[3]{\frac{1}{2\cdot\ell_S}\left(P_{E\ell a2}^3\cdot S_1 + P_{E2}^3\cdot S_2 + P_{E\ell d2}^3\cdot S_3 + P_{Era2}^3\cdot S_1 + P_{E2}^3\cdot S_2 + P_{Erd2}^3\cdot S_3\right)}$$

$$= \sqrt[3]{\frac{1}{2\times1450}\left(7958.9^3\times12.5+4459^3\times1400+3403.4^3\times37.5+1292.4^3\times12.5+4459^3\times1400+5625.7^3\times37.5\right)}$$

$$= 4491.2\ \text{N}$$

$$P_{m3} = \sqrt[3]{\frac{1}{2\cdot\ell_S}\left(P_{E\ell a3}^3\cdot S_1 + P_{E3}^3\cdot S_2 + P_{E\ell d3}^3\cdot S_3 + P_{Era3}^3\cdot S_1 + P_{E3}^3\cdot S_2 + P_{Erd3}^3\cdot S_3\right)}$$

$$= \sqrt[3]{\frac{1}{2\times1450}\left(6978.9^3\times12.5+3479^3\times1400+2423.4^3\times37.5+312.4^3\times12.5+3479^3\times1400+4645.7^3\times37.5\right)}$$

$$= 3519.7\ \text{N}$$

$$P_{m4} = \sqrt[3]{\frac{1}{2\cdot\ell_S}\left(P_{E\ell a4}^3\cdot S_1 + P_{E4}^3\cdot S_2 + P_{E\ell d4}^3\cdot S_3 + P_{Era4}^3\cdot S_1 + P_{E4}^3\cdot S_2 + P_{Erd4}^3\cdot S_3\right)}$$

$$= \sqrt[3]{\frac{1}{2\times1450}\left(0\times12.5+1911^3\times1400+3077.7^3\times37.5+5410.9^3\times12.5+1911^3\times1400+855.4^3\times37.5\right)}$$

$$= 1983.7\ \text{N}$$

Nominal Life L_{10mn}

The nominal life of the four LM blocks is obtained from the corresponding nominal life equations shown below.

$$L_{10m1} = \left(\alpha\times\frac{C}{P_{m1}}\right)^3\times50 = 160100\ \text{km}$$

$$L_{10m2} = \left(\alpha\times\frac{C}{P_{m2}}\right)^3\times50 = 44900\ \text{km}$$

$$L_{10m3} = \left(\alpha\times\frac{C}{P_{m3}}\right)^3\times50 = 93300\ \text{km}$$

$$L_{10m4} = \left(\alpha\times\frac{C}{P_{m4}}\right)^3\times50 = 521000\ \text{km}$$

$$\alpha = \frac{1}{f_W}\ \text{(where } f_W = 1.5\text{)}$$

Therefore, the service life of the LM Guide used in a machine or equipment under the conditions stated above is equivalent to the nominal life of the second LM block, which is 44,900 km.

Example of Calculating the Nominal Life (2) - with Vertical Mount

Operating Conditions

Model No. : HSR25CA2SS+1500L-Ⅱ
(basic dynamic load rating: C = 27.6 kN)
(basic static load rating: C_0 = 36.4 kN)

Mass : m_0 = 100 kg
m_1 = 200 kg
m_2 = 100 kg

Stroke : ℓ_S = 1000 mm

Distance : ℓ_0 = 300 mm
ℓ_1 = 80 mm
ℓ_2 = 50 mm
ℓ_3 = 280 mm
ℓ_4 = 150 mm
ℓ_5 = 250 mm

The mass (m_0) is loaded only during ascent; it is removed during descent.

Gravitational acceleration g = 9.8 (m/s²)

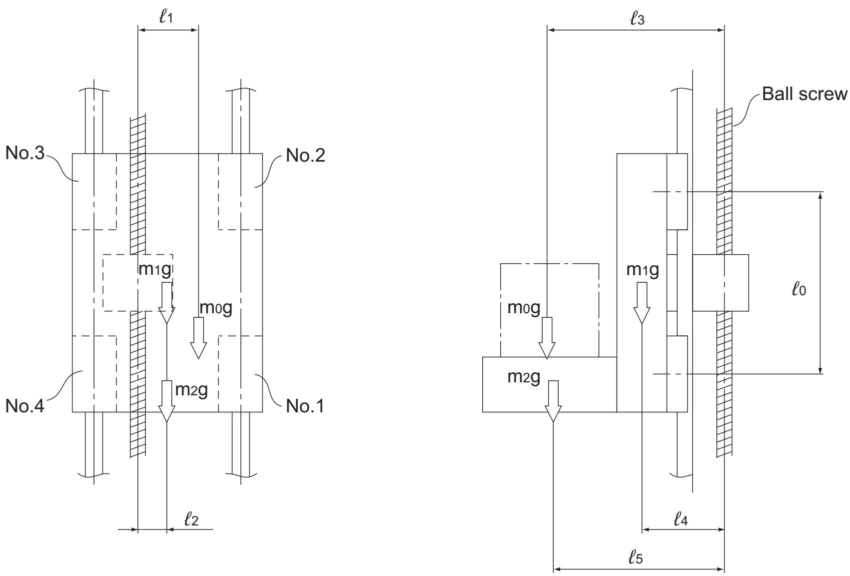


Fig. 13: Operating Conditions

Load Applied to the LM Block

● During Ascent

■Load applied to each LM block in the radial direction Pu_n during ascent

$$Pu_1 = +\frac{m_1 g \cdot \ell_4}{2 \cdot \ell_0} + \frac{m_2 g \cdot \ell_5}{2 \cdot \ell_0} + \frac{m_0 g \cdot \ell_3}{2 \cdot \ell_0} = +1355.6\ \text{N}$$

$$Pu_2 = -\frac{m_1 g \cdot \ell_4}{2 \cdot \ell_0} - \frac{m_2 g \cdot \ell_5}{2 \cdot \ell_0} - \frac{m_0 g \cdot \ell_3}{2 \cdot \ell_0} = -1355.6\ \text{N}$$

$$Pu_3 = -\frac{m_1 g \cdot \ell_4}{2 \cdot \ell_0} - \frac{m_2 g \cdot \ell_5}{2 \cdot \ell_0} - \frac{m_0 g \cdot \ell_3}{2 \cdot \ell_0} = -1355.6\ \text{N}$$

$$Pu_4 = +\frac{m_1 g \cdot \ell_4}{2 \cdot \ell_0} + \frac{m_2 g \cdot \ell_5}{2 \cdot \ell_0} + \frac{m_0 g \cdot \ell_3}{2 \cdot \ell_0} = +1355.6\ \text{N}$$

■Load applied to each LM block in the lateral direction Ptu_n during ascent

$$Ptu_1 = +\frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} + \frac{m_2 g \cdot \ell_2}{2 \cdot \ell_0} + \frac{m_0 g \cdot \ell_1}{2 \cdot \ell_0} = +375.7\ \text{N}$$

$$Ptu_2 = -\frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} - \frac{m_2 g \cdot \ell_2}{2 \cdot \ell_0} - \frac{m_0 g \cdot \ell_1}{2 \cdot \ell_0} = -375.7\ \text{N}$$

$$Ptu_3 = -\frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} - \frac{m_2 g \cdot \ell_2}{2 \cdot \ell_0} - \frac{m_0 g \cdot \ell_1}{2 \cdot \ell_0} = -375.7\ \text{N}$$

$$Ptu_4 = +\frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} + \frac{m_2 g \cdot \ell_2}{2 \cdot \ell_0} + \frac{m_0 g \cdot \ell_1}{2 \cdot \ell_0} = +375.7\ \text{N}$$

● During Descent

■Load applied to each LM block in the radial direction Pd_n during descent

$$Pd_1 = +\frac{m_1 g \cdot \ell_4}{2 \cdot \ell_0} + \frac{m_2 g \cdot \ell_5}{2 \cdot \ell_0} = +898.3\ \text{N}$$

$$Pd_2 = -\frac{m_1 g \cdot \ell_4}{2 \cdot \ell_0} - \frac{m_2 g \cdot \ell_5}{2 \cdot \ell_0} = -898.3\ \text{N}$$

$$Pd_3 = -\frac{m_1 g \cdot \ell_4}{2 \cdot \ell_0} - \frac{m_2 g \cdot \ell_5}{2 \cdot \ell_0} = -898.3\ \text{N}$$

$$Pd_4 = +\frac{m_1 g \cdot \ell_4}{2 \cdot \ell_0} + \frac{m_2 g \cdot \ell_5}{2 \cdot \ell_0} = +898.3\ \text{N}$$

■Load applied to each LM block in the lateral direction Ptd_n during descent

$$Ptd_1 = +\frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} + \frac{m_2 g \cdot \ell_2}{2 \cdot \ell_0} = +245\ \text{N}$$

$$Ptd_2 = -\frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} - \frac{m_2 g \cdot \ell_2}{2 \cdot \ell_0} = -245\ \text{N}$$

$$Ptd_3 = -\frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} - \frac{m_2 g \cdot \ell_2}{2 \cdot \ell_0} = -245\ \text{N}$$

$$Ptd_4 = +\frac{m_1 g \cdot \ell_2}{2 \cdot \ell_0} + \frac{m_2 g \cdot \ell_2}{2 \cdot \ell_0} = +245\ \text{N}$$

Combined Radial and Thrust Load

● **During Ascent**

$P_{Eu1} = |P_{u1}| + |Pt_{u1}| = 1731.3$ N
$P_{Eu2} = |P_{u2}| + |Pt_{u2}| = 1731.3$ N
$P_{Eu3} = |P_{u3}| + |Pt_{u3}| = 1731.3$ N
$P_{Eu4} = |P_{u4}| + |Pt_{u4}| = 1731.3$ N

● **During Descent**

$P_{Ed1} = |Pd_1| + |Ptd_1| = 1143.3$ N
$P_{Ed2} = |Pd_2| + |Ptd_2| = 1143.3$ N
$P_{Ed3} = |Pd_3| + |Ptd_3| = 1143.3$ N
$P_{Ed4} = |Pd_4| + |Ptd_4| = 1143.3$ N

Static Safety Factor

The static safety factor (f_S) of the LM Guide used in a machine or equipment under the conditions stated above is obtained as follows.

$$f_S = \frac{C_0}{P_{EU2}} = \frac{36.4 \times 10^3}{1731.3} = 21.0$$

Average Load P_{mn}

Obtain the average load applied to each LM block.

$$P_{m1} = \sqrt[3]{\frac{1}{2 \cdot \ell_S}(P_{EU1}{}^3 \cdot \ell_S + P_{Ed1}{}^3 \cdot \ell_S)} = 1495.1 \text{ N}$$

$$P_{m2} = \sqrt[3]{\frac{1}{2 \cdot \ell_S}(P_{EU2}{}^3 \cdot \ell_S + P_{Ed2}{}^3 \cdot \ell_S)} = 1495.1 \text{ N}$$

$$P_{m3} = \sqrt[3]{\frac{1}{2 \cdot \ell_S}(P_{EU3}{}^3 \cdot \ell_S + P_{Ed3}{}^3 \cdot \ell_S)} = 1495.1 \text{ N}$$

$$P_{m4} = \sqrt[3]{\frac{1}{2 \cdot \ell_S}(P_{EU4}{}^3 \cdot \ell_S + P_{Ed4}{}^3 \cdot \ell_S)} = 1495.1 \text{ N}$$

Nominal Life L_{10mn}

The nominal life of the four LM blocks is obtained from the corresponding nominal life equations shown below.

$$L_{10m1} = \left(\alpha \times \frac{C}{P_{m1}}\right)^3 \times 50 = 182000 \text{ km}$$

$$L_{10m2} = \left(\alpha \times \frac{C}{P_{m2}}\right)^3 \times 50 = 182000 \text{ km}$$

$$L_{10m3} = \left(\alpha \times \frac{C}{P_{m3}}\right)^3 \times 50 = 182000 \text{ km}$$

$$L_{10m4} = \left(\alpha \times \frac{C}{P_{m4}}\right)^3 \times 50 = 182000 \text{ km}$$

$$\alpha = \frac{1}{f_W} \quad (\text{where } f_W = 1.2)$$

Therefore, the service life of the LM Guide used in a machine or equipment under the conditions stated above is 182,000 km.