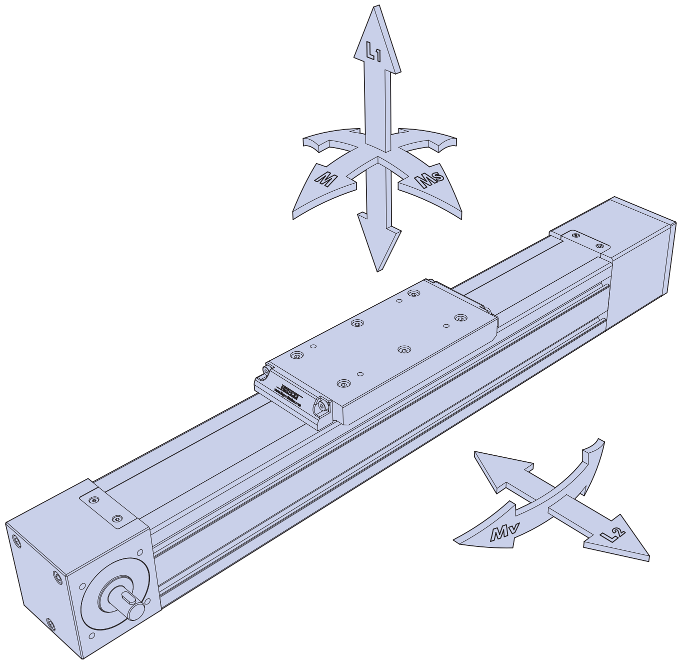
HepcoMotion®

SBD Load Life Calculations



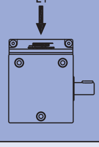
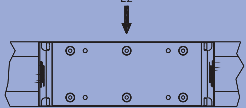
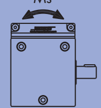
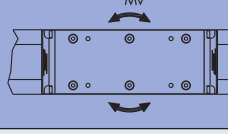
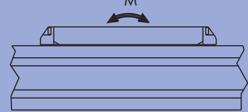
The life of an SBD system is calculated in terms of the number of kilometres that the system can travel before the linear ball guide reaches its L_{10} service life. The service life is expressed by the number of kilometres reached or exceeded by 90% of a representative sample of identical linear ball guides before the first signs of material fatigue become evident.

The life of an SBD system will be affected by a number of factors including the magnitude of the load on the system; the position of the load on the carriage plate the speed at which the system operates and the inertial forces acting on the system due to acceleration and deceleration.

To calculate the life of an SBD unit, the sytems load factor L_F must first be determined using the following equation:

$$L_F = \frac{L_1}{L_{1(max)}} + \frac{L_2}{L_{2(max)}} + \frac{M_S}{M_{S(max)}} + \frac{M}{M_{(max)}} + \frac{M_V}{M_{V(max)}} \leq 0.2 \qquad \text{equation 1}$$

The maximum values for L_1, L_2, M_S, M and M_V are given in the table below:

SBD Unit					
SBD20-80	21200N nominal 1813N @ 10 000km	21200N nominal 1813N @ 10 000km	189Nm nominal 16.2Nm @ 10 000km	175Nm nominal 14.9Nm @ 10 000km	175Nm nominal 14.9Nm @ 10 000km
SBD30-100	52100N nominal 4455N @ 10 000km	52100N nominal 4455N @ 10 000km	639Nm nominal 54Nm @ 10 000km	755Nm nominal 64Nm @ 10 000km	755Nm nominal 64Nm @ 10 000km

* The tabulated load figures above for 10 000km assume a value for variable load factor $f_v = 2$.

Note: f_v is the variable load factor which takes account of speed and vibration/impact conditions acting upon an SBD unit. A value of 2 is appropriate for most SBD applications, but f_v may vary in line with the data below.

Impact and Vibration Condition	Travel Speed Velocity (V)	fv
No External Impact or Vibration	$V \leq 15$m / min (Low Speed)	1 - 1.5
Slight Impact and Vibration	$15 < V \leq 60$m / min (Medium Speed)	1.5 - 2.0
Medium Impact and Vibration	$V > 60$m / min (High Speed)	2.0 - 3.5

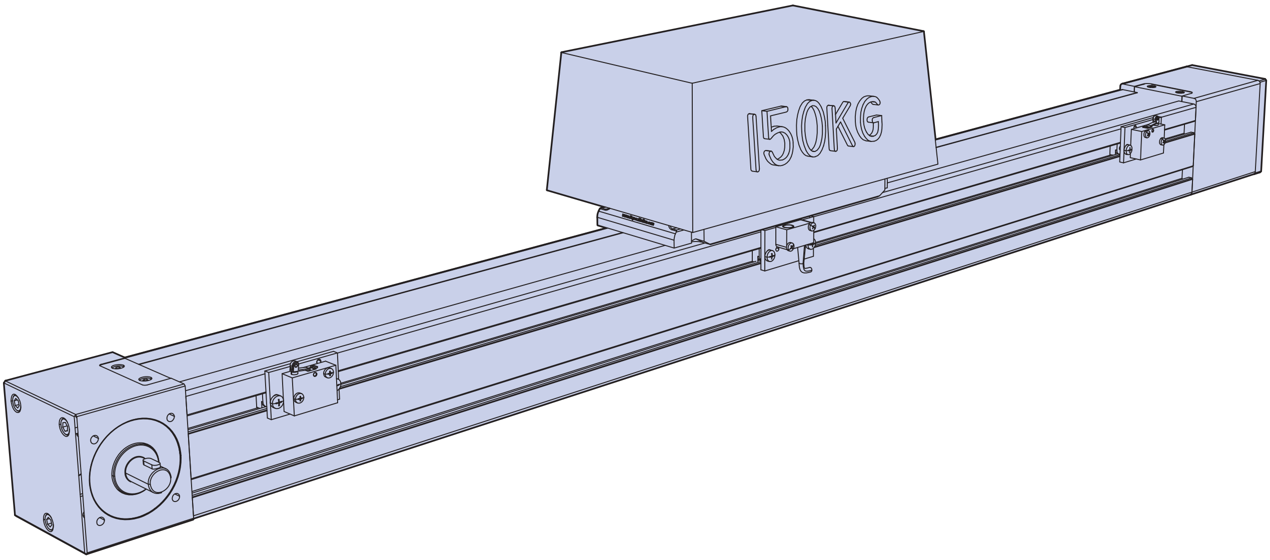
The life of the system is then calculated using the equation below:

$$\text{System Life (km)} = 50 \times \left(\frac{1}{L_F \times f_v}\right)^3 \qquad \text{equation 2}$$

SBD Load Life Calculations

Example 1

An SBD20-80 unit is used in an application where it moves a mass of 150kg up and down its length. The system accelerates slowly and moves at an average speed 0.5m/s, thus inertial forces can be ignored. The system operates on a 75% duty cycle for 40 hours per week. The mass is positioned centrally on the carriage – see image.



L_1 is therefore the only force acting on the SBD unit, $L_1 = 150kg \times 9.81m/s^2 = 1471.5N$.
Entering values into equation 1 gives:

$$L_F = \frac{1471.5}{21200} = 0.0694$$

Substituting L_F into equation 2 and assuming fv = 2 gives the linear life of the system:

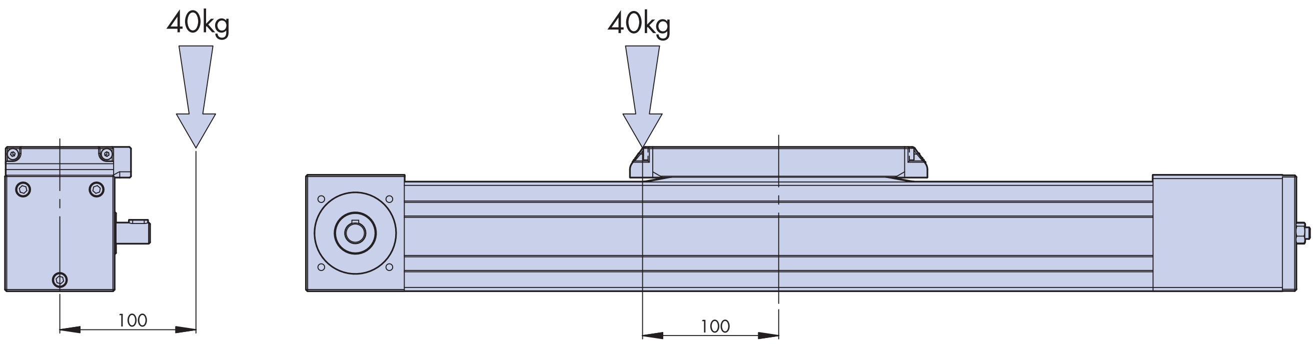
$$\text{System Life (km)} = 50 \times \left(\frac{1}{0.0694 \times 2}\right)^3 = 18700\text{km}$$

To calculate the life of the system in years we firstly need to calculate the number of kilometers travelled per week:
Distance / week (km) = (0.75 (duty cycle) x 40hrs x 3600s) x 0.5m/s = 54km/week
Therefore the system life can be calculated in number of weeks:

$$\text{System Life} = \frac{18700\text{ km}}{54\text{ km / wk}} = 346\text{ weeks} \approx 6.6\text{ years}$$

Example 2

An SBD30-100 unit is used in an application where it moves a mass of 40kg up and down its length. The system accelerates slowly and moves at an average speed of 0.2m/s, thus inertial forces can be ignored. The system runs on a 50% duty cycle for 40 hours per week. The mass is offset from the centre of the carriage. The figure below shows the position of the centre of mass relative to the centre of the carriage.



In this case there are components of L_1, M and M_S acting on the system:
$L_1 = 40kg \times 9.81m/s^2 = 392.4N$ $M = 0.1m \times 40kg \times 9.81m/s^2 = 39.2Nm$ $M_S = 0.1m \times 40kg \times 9.81m/s^2 = 39.2Nm$

Entering these values into equation 1 along with the maximum values given in the table gives:

$$L_F = \frac{392.4}{52100} + \frac{39.2}{639} + \frac{39.2}{755} = 0.1208$$

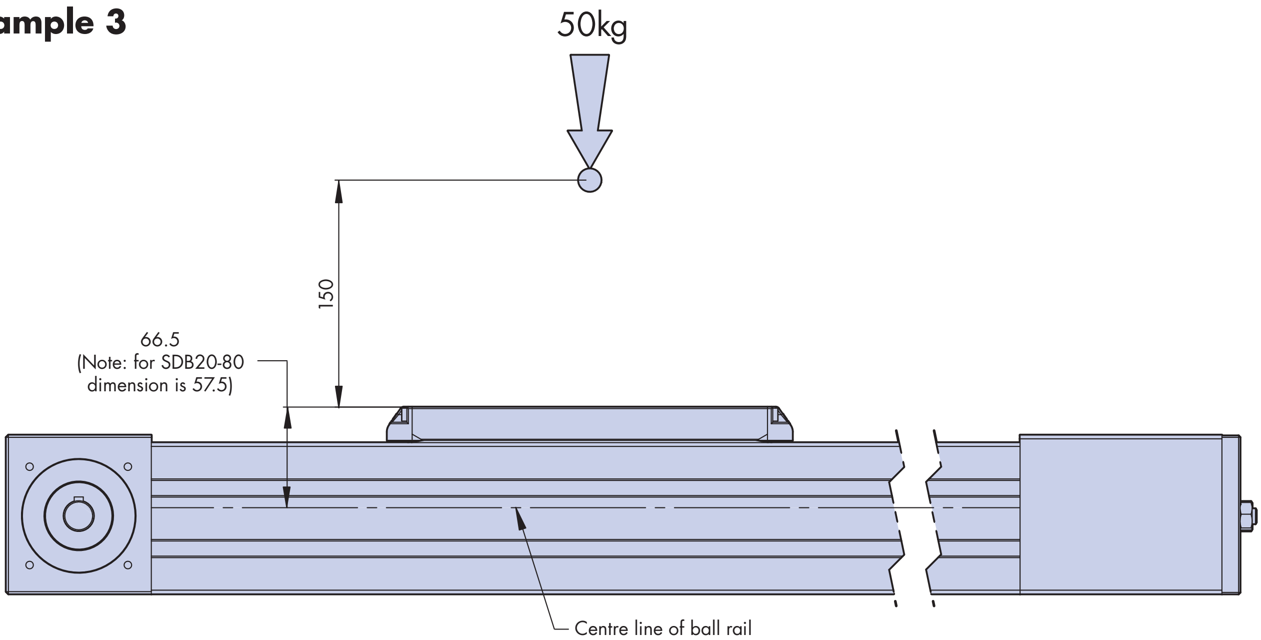
Substituting L_F into equation 2 and assuming fv = 1.5 gives the linear life of the system:

$$\text{System Life (km)} = 50 \times \left(\frac{1}{0.1208 \times 1.5}\right)^3 = 8404\text{km}$$

To calculate the life of the system in years we firstly need to calculate the number of kilometres travelled per week:
Distance / week (km) = (0.5 (duty cycle) x 40hrs x 3600s) x 0.2m/s = 14.4km/week
Therefore the system life can be calculated in number of weeks:

$$\text{System Life} = \frac{8404 \text{ km}}{14.4 \text{ km/wk}} = 583.6 \text{ weeks} \approx 11.2 \text{ years}$$

Example 3



An SBD30-100 unit is used in an application where a mass of 50kg is moved up and down its length over a 4m stroke. The mass is positioned centrally on the carriage with its centre of mass 0.150m above the top of the carriage plate, which in turn is 0.065m above the centre of the linear ball guide, which is the point through which the moment acts – see figure above. The mass is accelerated at a rate of $2m/s^2$ for a distance of 1m it then travels at a constant speed of 2m/s for a distance of 2m then decelerates to a stop at a rate of $2m/s^2$ in the final meter of the stroke. The return stroke follows the same sequence of movement. The system operates on a 60% duty cycle for 150 hours per week.

In this case inertial forces cannot be ignored since the acceleration rates are significant. During the acceleration and deceleration phases on the stroke moment loads act on the carriage. To enable the effect this has on the life on the system, the time fraction for the acceleration and deceleration phases must first be calculated. The time spent accelerating in a given stroke is calculated using the following equation of motion:

$$v = u + at$$

Where 'v' is final velocity, 'u' is initial velocity, 'a' is acceleration and 't' is time.
Rearranging the above equation and substituting values gives:

$$t = \frac{v - u}{a} = \frac{2m/s - 0m/s}{2m/s^2} = 1s$$

Since the deceleration rate is also $2m/s^2$ the time taken to slow the carriage from 2m/s to rest is also 1s. The time spent at constant velocity is 1s for every stroke, since the carriage travels 2m at 2m/s. The total time for each stroke is therefore 3s and the time spent is each phase of the stroke is as follows; accelerating = 33.3% of the total stroke time, constant velocity = 33.3% of the total stroke time, and decelerating = 33.3% of the total stroke time.

During the acceleration and deceleration phases of the stroke L_1 and M loads act on the system:

$$L_1 = 50kg \times 9.81m/s^2 = 490.5N \qquad M = (0.15m + 0.0665m) \times 50kg \times 2m/s^2 \approx 21.65Nm$$

During the constant velocity phase of the stoke only the L_1 load acts on the system. Since the load factor L_F will be varying during the stroke it will need to be calculated for each phase of the stroke, since the acceleration and deceleration rates are the same the L_F factor will be the same for those times.

SBD Load Life Calculations

For the acceleration and deceleration phases of the stroke the Load Factor LF_A will be:

$$LF_A = \frac{490.5}{52100} + \frac{21.65}{755} = 0.0381$$

For the constant velocity phase of the stroke the Load Factor LF_C will be:

$$LF_C = \frac{490.5}{52100} = 0.00941$$

Where the load factor varies the average load factor can be calculated as follows:

$$LF = \sqrt[3]{LF_1^3 \times \frac{q_1}{100} + LF_2^3 \times \frac{q_2}{100} \ldots + LF_x^3 \times \frac{q_x}{100}}$$

Where q = time fraction (%)

Substutng the above figure for load factor into this equation:

$$LF = \sqrt[3]{0.0381^3 \times \frac{33.3}{100} + 0.00941^3 \times \frac{33.3}{100} + 0.0381^3 \times \frac{33.3}{100}} = 0.03336$$

Substituting LF into equation 2 and assuming fv = 2 gives the linear life of the system:

$$\text{System Life (km)} = 50 \times \left(\frac{1}{0.03336 \times 3}\right)^3 = 49880\text{km}$$

To calculate the life of the system in years we firstly need to calculate the number of kilometres travelled per week:

The time to travel the 4m stroke has been calculated to be 3s, therefore the distance travelled in one week can be calculated:
Distance / week (km) = (0.6 (duty cycle) x 150hrs x 3600s) x (4m / 3s) = 432km/week
Therefore the system life can be calculated in number of weeks:

$$\text{System Life} = \frac{49880 \text{ km}}{432 \text{ km/wk}} = 115.5 \text{ weeks} \approx 2.2 \text{ years}$$

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