Linear Step Motors

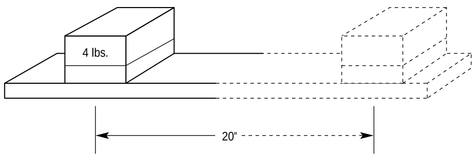
There are many characteristics to consider when designing, selecting and installing a complete motion control system. The applications data worksheet and the application considerations detailed below will help determine if a linear motor system is recommended for a given application. A linear motor, when properly specified, will provide the optimum performance and the greatest reliability.

Application Data Worksheet #1

Application: Single Axis [√] Multi-Axis [ ] X-Y Gantry [ ]

Description of system operation: A part is moved in and out of a machine very quickly. The part comes to rest at the same point in the machine each time. An operator sets this distance with a thumbwheel switch.

Sketch the proposed mechanical configuration:



		AXIS 1
1.	Motor Sizing	
	A. Weight of payload (lbs)	10.0
	B. Fixed forces, if any (lbs)	0
	C. Known move distance (in)	40
	time (sec)	1.0
	D. Angle from horizontal (degrees)	0
2.	Total length of travel (inches)	40
3.	Desired repeatability (in)	001
4.	Desired resolution (in)	.0005
5.	Necessary settling time after move 100 ms to within	.001 inches
6.	Life expectancy:	
	Percent duty cycle	20%
	Estimated number of moves/year	200,000
7.	Is the center of gravity significantly changed?	no
8.	What is the environment? clean [√] dirty [ ]	
	Specifics	
9.	Operating temperature range	65° to 85°F
10.	Can air be available?	yes

The Solution

Actual and assumed factors that contribute to the solution are:

1. Force (F) = mass (M) x acceleration (A)
   Note: mass units are in pounds
2. Acceleration due to gravity
   ($1g=386$ inches/sec^2)
3. L20 forcer weighs 2.0 lb.
4. Attractive force between L20 forcer and platen = 200 lbs.
5. Trapezoidal velocity profile:
   Accel time = 1.0 sec/4
   = 0.250 sec.
   Vmax = 1.33 x Vavg

Step 1: Total mass to be accelerated

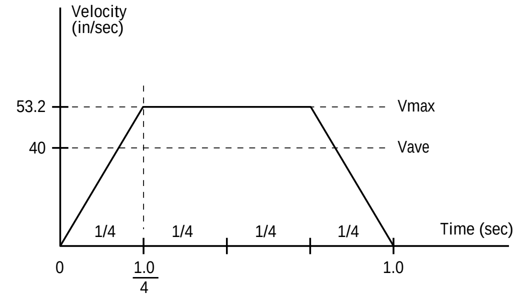
Mtotal = Mload (10.0) + Mforcer (2.0) = 12.0 lbs.

Step 2: Acceleration rate

A. Average velocity

$$= \frac{\text{move distance}}{\text{move time}} = \frac{(40 \text{ inches})}{(1.0 \text{ sec})} = 40.0 \text{ in/sec}$$

B. Maximum velocity
(Based on trapezoidal move profile)
Vmax = 1.33 x Vavg (40.0 in/sec)
= 53.2 in/sec



C. Minimum acceleration rate

$$A = \frac{\text{Vmax } (53.2 \text{ in/sec})}{\text{Accel. time } (.250 \text{ sec})} = 212.8 \text{ in/sec}^2$$

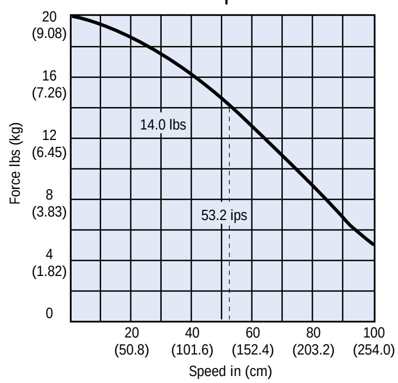
$$A = \frac{\text{Minimum acceleration } (212.8 \text{ in/sec}^2)}{386 \text{ in/sec}^2 \text{ per 1 G}}$$

= 0.551 g's

Step 3: Calculate maximum acceleration rate of L20 (using constant acceleration indexer).

Based on the speed/force curve below, the L20 has 14.0 lbs of force at 53.2 in/sec (Vmax).

Force vs. Speed L-L20



Step 4: Non-damped safety margin

If all available force could be used, the maximum calculated acceleration rate:

$$\text{Amax} = \frac{\text{Force } (14.0 \text{ lb})}{\text{Mtotal } (12.0 \text{ lbs.})} = 1.16 \text{ g's}$$

The calculated acceleration rate should be reduced by 50% (100% non-damped safety margin) netting an acceleration rate for the L20 of 0.58 g's. The application requires a 0.55 g's acceleration rate. The L20 meets the requirements of this application.

Velocity Ripple

Velocity ripple is most noticeable when operating near the motor's resonant frequency. Rotary stepping motor's have this tendency as well, but it is usually less noticeable due to mechanical losses in the rotary-to-linear transmission system, which dampens the effects. Velocity ripple due to resonance can be reduced with the electronic accelerometer damping option (-AC).

Platen Mounting

The air gap between the forcer and the platen surface can be as small as 0.0005 inches. Properly mounting the platen is extremely important. When held down on a magnetic chuck, the platen is flat and parallel within its specifications, however, in its free state, slight bows and twists may cause the forcer (L20) to touch the platen at several places. Compumotor recommends mounting the platen using *all* its mounting holes on a ground flat piece of steel, such as an I-beam, U-channel or tube.

Environment

Due to the small air gap between the forcer and platen, care should be taken to keep the platen clean. A small amount of dirt or adhesive material (such as paint) can cause a reduction in motor performance. When appropriate, mounting the motor upside down or on its side will help keep foreign particles off the platen. Protective boots that fold like an accordion as the motor travels can also be used to assist in keeping the platen clean.

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Life Expectancy

The life of a mechanical bearing motor is limited by wearing of the platen surface over which the bearings roll. Factors that affect wear and life of a mechanical bearing system include:

A. High velocities – Life is inversely proportional to velocity cubed. Increasing velocity raises the temperature of the platen due to eddy current losses in the solid platen material. (In normal high-speed, high duty cycle operation over a small piece of platen, the platen can become almost too hot to touch.)

B. Load on the forcer – Load has some effect on the life expectancy of the linear motor. Users are urged to adhere to the load specifications for each motor.

Yaw, Pitch and Roll

In applications such as end effector devices or where the load is located far from the motor's center of gravity, the stiffness characteristics of the forcer must be considered. Moment producing forces tend to deflect the forcer, and if strong enough, will cause the motor to stall or be removed from the platen. Yaw, pitch and roll specifications are used to determine the maximum torque you can apply to the forcer.

Accuracy

In linear positioning systems, some applications require high absolute accuracy, while many applications require a high degree of repeatability. These two variables should be reviewed to accurately evaluate proper system performance.

In the "teach mode", a linear motor can be positioned and subsequently learn the coordinates of any given point. After learning a number of points in a sequence of moves, the user will be concerned with the ability of the forcer to return to the same position from the same direction. This scenario describes repeatability.

In a different application, a linear motor is used to position a measuring device. The size of an object can be measured by positioning the forcer to a point on the object. Determining the measured value is based on the number of steps required to reach the point on the object. System accuracy must be smaller than the tolerance on the desired measurement.

Open-loop absolute accuracy of a linear step motor is typically less than a precision grade leadscrew system. If a linear encoder is used in conjunction with a linear motor, the accuracy will be equivalent to any other transmission system.

The worst-case accuracy of the system is the sum of these errors:

Accuracy = A + B + C + D + E + F

A = Cyclic Error – The error due to motor magnetics that recurs once every pole pitch as measured on the body of the motor.

B = Unidirectional Repeatability – The error measured by repeated moves to the same point from different distances in the same direction.

C = Hysteresis – The backlash of the motor when changing direction due to magnetic non-linearity and mechanical friction.

D = Cumulative Platen Error – Linear error of the platen as measured on the body of the motor.

E = Random Platen Error – The non-linear errors remaining in the platen after the linear is disregarded.

F = Thermal Expansion Error – The error caused by a change in temperature expanding or contracting the platen.