A SIMPLE WAY TO SIZE LINEAR MOTORS

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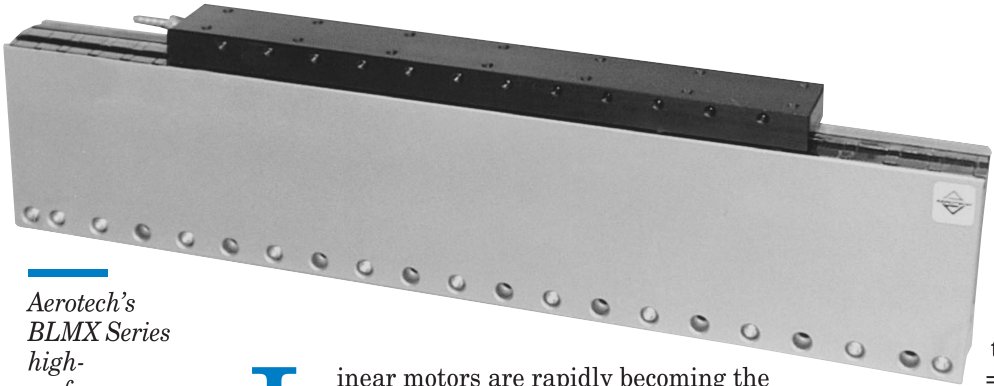
Sizing a linear motor can be simplified by using equal times for acceleration, velocity, and deceleration.



Aerotech's BLMX Series high-performance linear motors can accelerate a 50-kg load to 3.7 gs and make a 500-mm move in 250 msec.

Linear motors are rapidly becoming the technology of choice for motion control in numerous machines, especially for increasing throughput. The speed, acceleration, and positioning accuracy of linear-motor systems are unsurpassed by any other linear-motion technology.

For example, consider a 50-kg load (mass) that must move 500 mm in 250 msec, dwell for 275 msec, and then repeat. Find the required forces and size the linear motor.

The fundamental equations for calculating the required forces during a trapezoidal move are:

$$F_a = ma + F_f,$$

$$F_t = F_f,$$

$$F_d = -ma + F_f, \text{ and}$$

$$F_w = 0,$$

where m = mass, kg; a = acceleration, mm/sec/sec; F_a = force required to accelerate the load, lb; F_t = force required during traverse motion of the load, lb; F_d = force required to decelerate the load, lb; F_f = frictional force, lb; and F_w = force at dwell, lb.

First, determine the average speed required to make the move;

$$S_a = \frac{500 \text{ mm}}{250 \text{ msec}} = 2{,}000 \text{ mm / sec.}$$

The load cannot accelerate instantaneously from 0 to 2m/sec, so apply the equation for the most efficient move — a trapezoidal move with constant acceleration. Divide 250 msec into three equal parts: one-third acceleration, one-third traverse, and one-third deceleration, or 250 msec/3 = 83.3 msec.

The average speed must be multiplied by a factor of 1.5 to ensure the load will make the move in 250 msec over the three symmetrical segments. With this technique, the peak speed of the move is

$$S_p = 1.5 \times 2{,}000 \text{ mm / sec}$$
$$= 3{,}000 \text{ mm / sec.}$$

This means the load must accelerate from rest to 3,000 mm/sec (3m/sec). Newton's equation finds the force:

$$F_a = ma$$
$$= \frac{(50 \text{ kg})(3 \text{ m / sec})}{83.3 \text{ msec}}$$
$$= (50 \text{ kg})(36 \text{ m / sec / sec})$$
$$= 1{,}800 \text{ N or } 405 \text{ lb.}$$

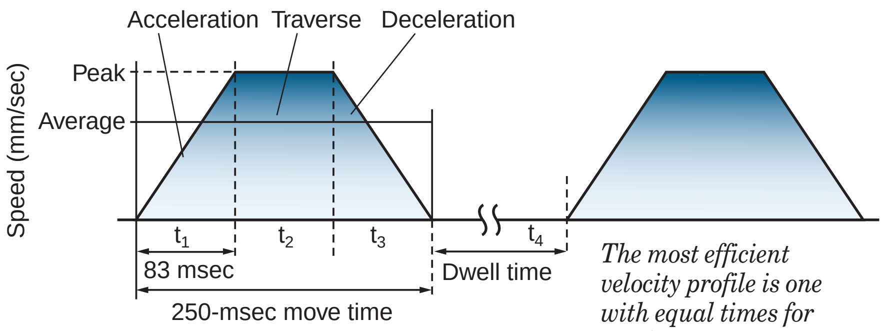
This is the peak rating needed from the prospective motor, derived only from acceleration force. It does not account for friction or other opposing forces. For example, a quality cross-roller bearing used to carry the load has a coefficient of friction of about 0.0005 to 0.003. When the 50 kg rides on these bearings, the frictional force is

$$F_f = (0.003)(50 \text{ kg})$$
$$= 0.15 \text{ kg}$$
$$= 0.33 \text{ lb.}$$

The frictional force is low because the linear bearings are highly efficient. And because fric-

You can find related information at: www.penton.com/md/bde/electrical/index.html (1.8 Ac linear motors, 1.20 Dc linear motors)

Velocity profile



The most efficient velocity profile is one with equal times for acceleration, traverse, and deceleration.

tion always opposes motion, it adds to the driving force required; 405 lb + 0.33 lb = 405.33 lb. Next, with a known total acceleration force, determine the rms or continuous-force requirement. The rms force is the major contributor to the temperature rise of the linear motor's forcer coil, which ultimately limits the power output. This is where the duty cycle enters the equation. For the example, the duty cycle:

$$
\begin{aligned}
t_{dc} &= t_{on} / (t_{on} + t_{off}) \\
&= 250 \text{ msec} / (250 \text{ msec} + 275 \text{ msec}) \\
&= 0.476 \text{ or } 47.6\%.
\end{aligned}
$$

Apply the rms force equation to calculate the system needs on a continuous basis:

$$F_{rms} = \sqrt{\frac{(F_a)^2(t_1) + (F_t)^2(t_2) + (F_d)^2(t_3)}{t_1 + t_2 + t_3}}$$

$$F_{rms} = \sqrt{\frac{(405.33 \text{ lb})^2(83 \text{ msec}) + (0.33 \text{ lb})^2(83 \text{ msec}) + (405 \text{ lb} - 0.33 \text{ lb})^2(83 \text{ msec})}{525 \text{ msec}}}$$

$$F_{rms} = 227.7 \text{ lb} \ \ (1{,}013 \text{ N})$$

Use the rms force, 227.7 lb, to choose a specific model from a linear motor catalog that can apply this force continuously. Adding air cooling can significantly increase the rms output force of a particular motor which allows a smaller forcer coil to maximize stroke length. ■