Calculating force

Calculating the translational force required to move a given load in a specific manner is the first step in sizing a linear actuator. In general, there are four components of force, or thrust, to overcome — that due to mass, gravity, friction, and associated counterforces such as spring, cutting, and pressing forces. The components are additive and must be summed for each portion of the move profile to determine the worst case criteria. A sample calculation illustrates the process.

Sample calculation

Calculate the thrust required to accelerate a 200 lb mass to 8 in./sec in 0.2 sec. Assume the load is on a ramp with an incline of 30° with a sliding coefficient of friction of 0.15. Also assume there's a 25 lb spring force opposite the direction of motion.

In calculating total force, the first step is to account for each of the four components.

$$T = F_f + F_a + F_g + F_p$$

Next, substitute the equations for the forces themselves.

$$T = W_L \mu \cos(\theta) + \frac{W_L}{386.4} \cdot \frac{v}{t_a} + W_L \sin\theta + F_p$$

Finally, calculate thrust using the values from the problem.

$$T = 200 \cdot 0.15 \cdot 0.866 + \frac{200}{386.4} \cdot \frac{8.0}{0.2} + 200 \cdot 0.5 + 25$$

$$= 26 + 20.73 + 100 + 25$$

$$= 171.73\ lbf$$

Questions & Answers

Q: What is a move profile?
A: A move profile is a plot of velocity over time, usually consisting of two or three linear segments. Triangular move profiles have two segments (acceleration and deceleration), while trapezoidal profiles have an additional segment (a region of constant velocity).

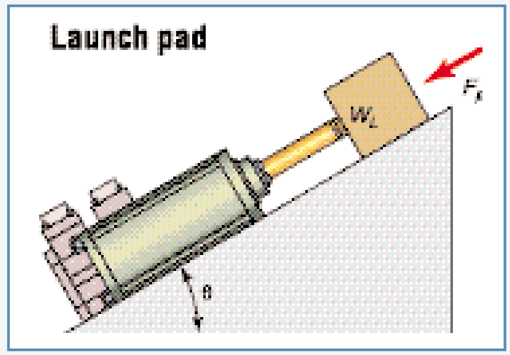
Q: Do triangular profiles offer an advantage?
A: Triangular move profiles minimize acceleration and deceleration. They can be used for any move where the average (required) velocity is less than half the maximum (output) velocity of the actuator.

Q: How do trapezoidal profiles compare?
A: To move the same distance in the same amount of time as a triangular profile, a trapezoidal profile (consisting of three equal segments) forces the actuator to accelerate and decelerate 12.5% faster, while limiting maximum speed by 25%.

Material for this month's MSD 101 provided by Exlar Corp., maker of linear actuators, Chanhassen, Minn.

Terms and units

T = total linear force (lbf)
F_f = force from friction (lbf)
F_a = acceleration force (lbf)
F_g = force due to gravity (lbf)
F_p = applied force (lbf)
W_L = weight of load (lbf)
U = angle of inclination (deg)
t_a = acceleration time (sec)
v = final velocity (in./sec)
μ = coefficient of sliding friction
g = acceleration of gravity = 386.4 in./sec^2

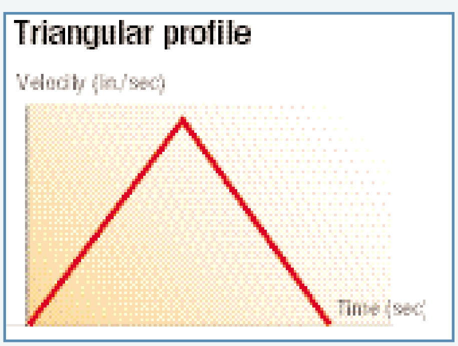


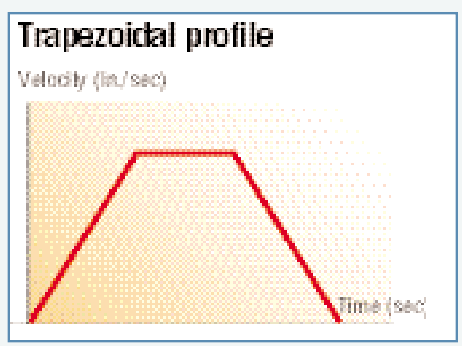
Coefficients of sliding friction

Materials in contact	μ
Steel on dry steel	0.58
Aluminum on steel	0.45
Brass on steel	0.44
Copper on steel	0.36
Plastic on steel	0.20
Steel on lubed steel	0.15
Linear bearings	0.001

Common material densities

Material	oz-in.^{3}	gm/cm^3
Copper (cast or hard drawn)	5.15	8.91
Brass (cast or rolled)	4.80	8.30
Bronze (cast)	4.72	8.17
Steel (hot or cold rolled)	4.48	7.75
Aluminum (cast or hard drawn)	1.54	2.66
Plastic	0.64	1.11
Wood (hard)	0.46	0.80
Wood (soft)	0.28	0.58





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