How to select and apply rail brakes

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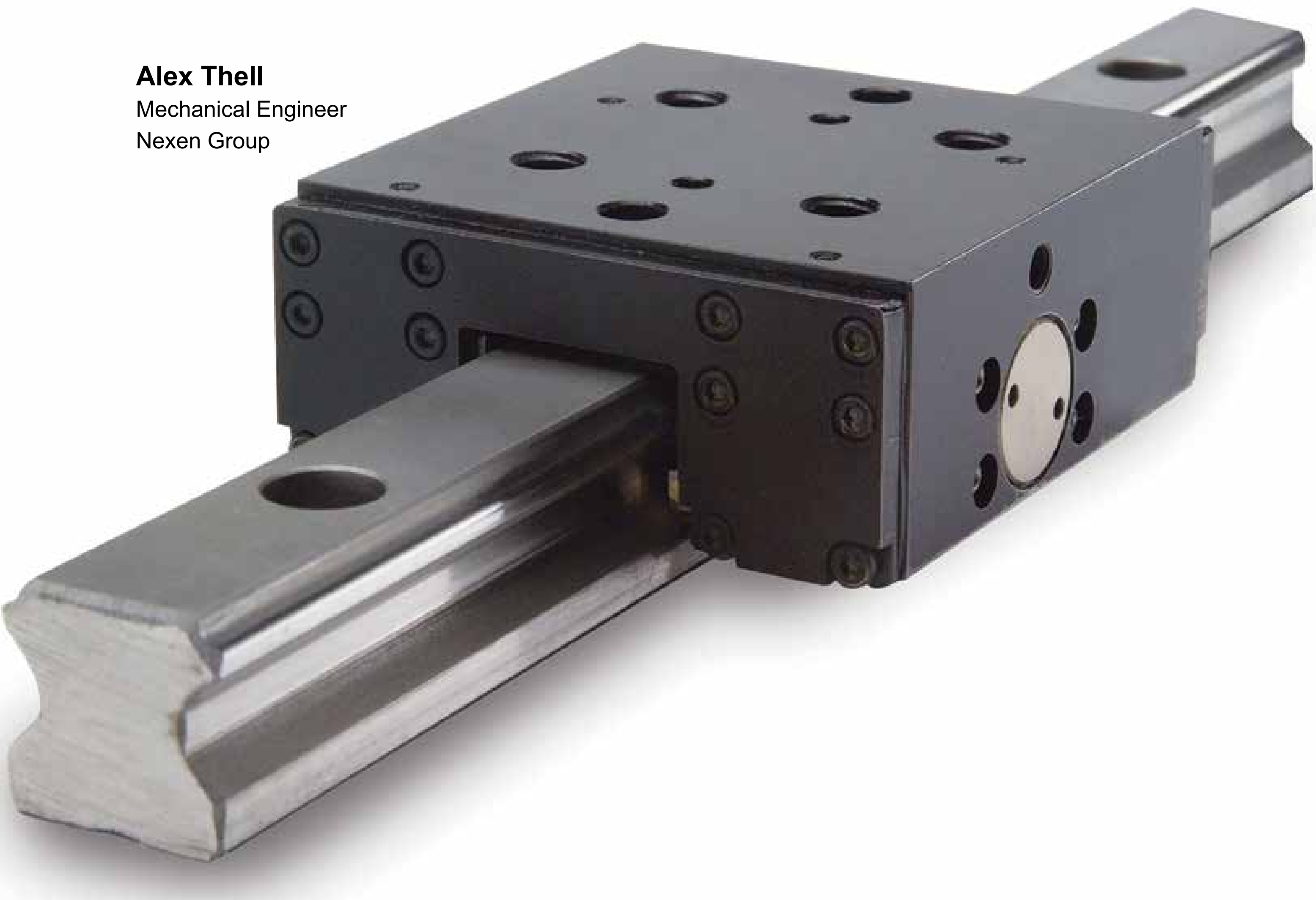
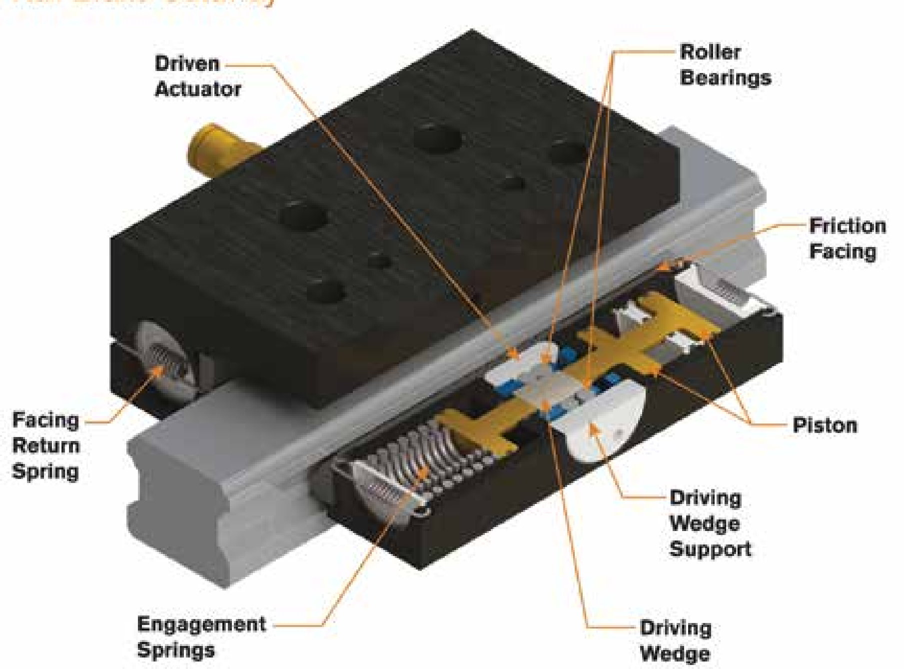


Linear guide rail brakes play a critical role in many linear motion applications by ensuring that the guide carriage and payload do not move under load.

Precision linear motion is an important requirement for a range of machinery such as packaging machines, metal-cutting machine tools, woodworking machines and medical systems, among others. Many linear motion applications require the ability to stop the motion at various points while work is performed. Rail brakes provide an efficient method of stopping linear motion by providing holding force on profile rail guides in a package small enough to work alongside linear bearing blocks. Rail brakes must be capable of providing reliable, high holding force while ensuring low backlash for accurate positioning. One very popular design uses a series of spring engaged/pneumatic released pistons to apply a clamping force. The design uses a wedge and roller mechanism on the non-bearing contact surface of the guide rail. Selecting the correct rail brake for a particular application begins with calculating the maximum holding force required by the application. Next, select a brake, or brakes, that will deliver that force while ensuring that the brake fits the profile rail.

Rail Brake Cutaway



Typical components of a linear motion system are the structural support system, bearing guides, profile rail slides and drive system. Linear profile rails are designed into the structural support with a carriage attached to the bearing guides. Actuation of the carriage moves the payload along the linear system to provide the required motion. Plain bearing linear guides rely on low-friction, sliding surfaces running directly on the profile rails to provide smooth, linear motion. Rolling element guides use sets of balls or cylindrical rollers to support the guides. In a recirculating element guide, the balls or rollers circulate within the guide whenever the guide moves with respect to the rail.

The payload of the linear motion system rides on the carriage, which is typically driven by an electric motor through a rack and pinion, ball screw, lead screw or belt drive, which converts the rotary motion into linear motion. Once the payload has been delivered to the proper position, there is often a requirement for the payload to be held stationary. This is normally required in order to provide stability and accuracy while work is being done. A typical example is a linear motion system that carries a robot arm used in pick-and-place assembly operations. The linear axis must be fixed in position in order to accurately maintain the position of the robot arm and ensure that reaction forces generated by the robot do not move the carriage on the rail. Fixing the position of the linear axis is critical since any movement of the carriage would interfere with the assembly operations.

How they work

Rail brakes ride under the carriage and are attached between the bearing blocks. The rail brake holds the carriage in position by applying friction to the profile rails. Rail brakes are carefully designed not to brake on the rail surfaces that engage with the bearings to ensure no reduction of bearing life. Most rail brakes are designed primarily for static load holding applications since the motor itself can be used to stop the payload dynamically. The rail brake provides rigidity and accurate positioning required to achieve high levels of quality and throughput in a range of operations such as CNC machining and precision assembly among others.

A popular rail brake design uses springs to apply clamping force through friction pads onto the profile rails, thus locking the payload of the linear motion system in position. The springs continuously deliver clamping force while pneumatic pistons provide the force needed to release the brake when they are actuated. In order to securely grip the rails, the friction facings on the rail brakes need to be designed to match the size and geometry of the rails. The larger the rails used in the application, the greater the holding force that the brakes are able to apply.

The spring engaged/pneumatic released approach previously mentioned provides consistent holding force by tightly pressing the friction facings against the rail. This approach provides low backlash (typically within 0.002 in.). Braking systems integral with the motor or drive system produce higher backlash because the backlash includes not only the backlash of the brakes, but also the backlash of the drive system.

The spring engaged/pneumatic released design also uses a low volume cylinder so it doesn't require as much compressed air as typical brakes.

Rail brake applications

Rail brakes are used in three primary applications. The first and most common is holding accurate machine position during normal machine operations, such as CNC machining, pick and place gantry machines, and robotic welding and assembly. The second common application is power-off holding, which is needed when the power supply is disconnected from the machine. This is typically required during maintenance or when the linear motion system is turned off between shifts. The third common rail brake application is emergency stop braking. Rail brakes are intended for holding applications with limited emergency stops. They should not be used for cyclic, dynamic braking activity in order to preserve the life of the friction facings. One key advantage of the spring engaged/pneumatic released braking approach is that it automatically stops the payload if the power should suddenly fail.

Selecting rail brakes

The first step in selecting the right rail brake is to determine the maximum holding force required by the application. In static holding, where the carriage comes to a stop before the brake is applied, heat buildup and wear on the brake are minimal. For applications where the rail is oriented horizontally, and therefore the payload is not subjected to gravitational forces, the minimum required static holding force is equal to the force exerted on the carriage by the operation that is performed by the payload of the linear motion device.

When the rail is oriented other than horizontally, the brake must also be able to absorb the gravitational forces acting on the carriage. These forces can be determined with the following formula:

$$F = m \cdot g\,(\sin\theta)$$

where
F = forces in Newtons
m = mass of the payload, carriage, and motor moving parts in kilograms
g = acceleration due to gravity
θ = angle of the rail with respect to horizontal axis

In emergency stops, the brake also has to absorb the kinetic energy built up by the carriage and payload of the linear motion device. In many such applications, a predetermined maximum allowable stopping distance has been determined. The formulas below can be used to predict horizontal or vertical stopping distance based on the holding force of the brake. Sample calculations are also provided based on the data below.

Brake model	RB25
Brake force (F)	1000 N (225 lb)
Brake engagement time (t_e)	0.050 sec
Acceleration due to gravity (g)	9.8 m/sec^2
Mass of load (m)	45.4 kg
Load velocity (V) RB25	0.50 m/sec

Sample data

Horizontal Travel **(X and Y axis)**

Stopping time at full brake force:

$$t_s = \frac{m \cdot V}{F} = \frac{45.4 \cdot 0.50}{1000} = 0.023 \text{ sec}$$

Total time elapsed during emergency stop:

$$t_T = t_e + t_s$$

$$t_T = 0.05 + 0.023 = 0.073 \text{ sec}$$

Distance of travel during brake engagement:

$$d_e = V \cdot t_e$$

$$d_e = (0.5) \cdot (0.050) = 0.025 \text{ m}$$

Distance of travel at full brake force:

$$d_s = \frac{0.5 \cdot m \cdot V^2}{F} = \frac{(0.5) \cdot 45.4 \cdot (0.5)^2}{1000}$$

$$d_s = 0.006 \text{ m}$$

Total travel distance during emergency stop:

$$d_T = d_s + d_e$$

$$d_T = 0.006 + 0.025 = 0.031 \text{ m (31 mm)}$$

In this example, the load will travel 31 mm (1.22 in.) from the time the RB25 engages until the system is brought to a complete stop 0.073 seconds later.

Vertical Travel (downward) (Z axis)

Stopping time at full brake force:

$$t_s = \frac{m \cdot (g \cdot t_e + V)}{F - (m \cdot g)}$$

$$t_s = \frac{(45.4) \cdot (9.8 \cdot 0.05 + 0.5)}{1000 - (45.4 \cdot 9.8)} = 0.081 \text{ sec}$$

Total elapsed time during emergency stop:

$$t_T = t_e + t_s$$

$$t_T = 0.05 + 0.081 = 0.131 \text{ sec}$$

Distance of travel during brake engagement:

$$d_e = (0.5 \cdot g) \cdot t_e{}^2) + V \cdot t_e$$

$$d_e = 0.5 \cdot (9.8) \cdot (0.05)^2 + (0.5) \cdot (0.05) = 0.037 \text{ m}$$

Distance of travel at full brake force:

$$d_s = 0.5 \cdot [t_e \cdot g + V] \cdot t_s$$

$$d_s = 0.5 \cdot [(0.05) \cdot (9.8) + 0.5] \cdot 0.081 = 0.040 \text{ m}$$

Total travel distance during emergency stop:

$$d_T = d_s + d_e$$

$$d_T = 0.037 + 0.040 = 0.077 \text{ sec}$$

In this example, the load will travel down 77 mm (3.03 in.) from the time the RB25 engages until the system is brought to a complete stop 0.131 seconds later.

These equations will help determine the maximum holding force required by the application. Choose a rail brake model with the required holding force that will also fit the guide rail used in the application. If the desired rail brake is not capable of providing the required force, the size of the rail must be increased, or multiple rail brakes must be used to hold the load. DW

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