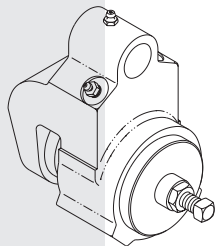
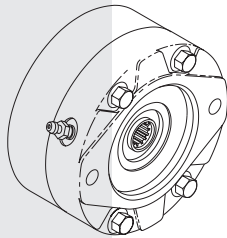
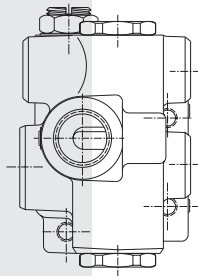
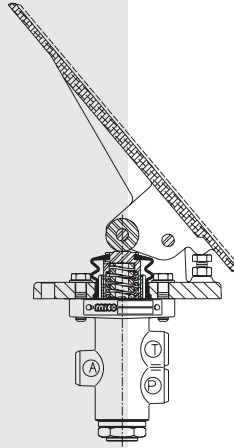




Selection Procedures for Brakes



*By David E. Keyser
Applications Coordinator
MICO, Incorporated*

*As seen in
Hydraulics and Pneumatics Magazine
November, 1992*

MICO designs, manufactures and sells hydraulic components and systems for heavy duty, off-road vehicles and equipment.

Selection procedures for brakes

Whether on an industrial machine or a piece of mobile, if a spinning shaft has to come to a controlled stop, it needs a brake

D.E. Keyser

Selecting a brake for any application — whether mobile or industrial, hydraulic or pneumatic — requires evaluating the same basic parameters. Torque required to stop a load and the heat generated in the process top the list of design concerns whenever selecting a brake. What differs between mobile and industrial applications is the emphasis placed on certain variables. Moreover, many industrial machines use brakes actuated by mechanical or electromechanical means, which are not included in this discussion.

Regardless of the type of actuation or whether the application is mobile or industrial, a number of different brake designs are available. These include drum and caliper disc (which are similar to those used in automobiles) and wet disc. The drum and disc types use a dry friction material that impinges on a steel surface. Wet disc types incorporate harder friction materials and a fluid that helps keep operating temperature low by carrying heat away from rubbing surfaces.

Brakes for industrial applications often require frequent, short-duration stopping cycles. Brakes for mobile applications, on the other hand, must be selected to handle worst-case conditions that can far exceed those of daily operation. To illustrate: a 60,000-lb vehicle with a 200-hp engine may climb a 6% grade at 20 mph. However, when descending that same grade at 30 mph would require 5760 braking hp to stop in 3 sec.

The other difference between most industrial and mobile brake applica-

tions is the method of actuation. In an industrial environment, easy access to compressed air or hydraulic fluid provides a convenient source of power to apply or release a brake using simple control valves. For mobile applications, the designer must supply a means of actuation — a non-boosted or boosted circuit or a full-power hydraulic brake system.

Industrial applications

Even though industrial applications may be viewed as more predictable than mobile, they are by no means less demanding. This is because high cycling rates often challenge the limits of brake performance. The least demanding applications are those with relatively low cycling rates — generally 5 stops per minute or less. Stopping torque and transmitted horsepower usually are the most important considerations for these applications. When brake cycles occur 5 to 6 times or more per minute, inertia, heat sink capacity, energy per cycle, and response time also require close scrutiny.

Beyond high cycling rates, stopping heavy rotating shafts or flywheels within a specific time period demands the highest performance from a brake. Having to stop a massive rotating shaft within 0.1 sec certainly is not unusual. Again, heat dissipation is important in high-inertia systems because brakes use friction to stop the load. Consequently, heat in the brake can build rapidly from stopping a load. This heat must be dissipated before another braking cycle occurs to avoid overheating.

Industrial selection

Selecting a brake for an industrial application can be relatively simple if the driven load has no heavy rotating parts that must be stopped within a specific time period. For these instances, brake torque corresponds to torque capacity of the prime mover multiplied by a service factor. A common service factor is 2.75 for Type B polyphase NEMA standard motors. In most cases, these pneumatically actuated brakes mount onto the motor.

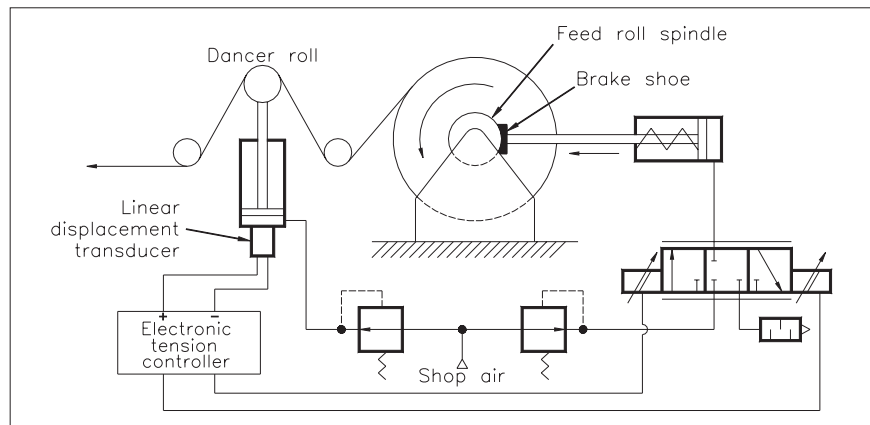


Fig. 1. Pneumatic brake keeps web tension constant by decreasing drag on spool as web unwinds. Regulated air pressure applied to cylinder acts as constant-compression spring that produces linear displacement of rod proportional to change in tension. Linear-displacement transducer then transmits proportional electronic signal to controller, which commands regulator to increase or decrease pressure to pneumatic brake.

However, when the driven load has heavy rotating members that must be stopped within a specific period, torque capacity should be calculated using the following formula:

$$T = (WK^2)\Delta N/308t,$$

where:

- T = torque required, lb-ft
- WK^2 = total inertia of load, lb-ft²
- ΔN = change in speed, rpm
- t = time, sec.

A brake may be capable of delivering more than enough torque to stop a load within the time allocated, but if the brake cannot dissipate the heat generated from braking before the next cycle begins, performance, reliability, and, especially, life can suffer.

Thermal horsepower is used to measure a brake's ability to dissipate heat. It is calculated using this formula:

$$HP_T = 0.00017(WK^2)\Delta N^2R/33,000,$$

where:

- HP_T = thermal horsepower
- R = rate of engagement, cycles/min.

The calculated value of thermal horsepower is compared with the thermal rating of the brake to ensure that the brake is appropriate for the application.

In addition to standard pneumatic and hydraulic brakes, many industrial

Modular brake system

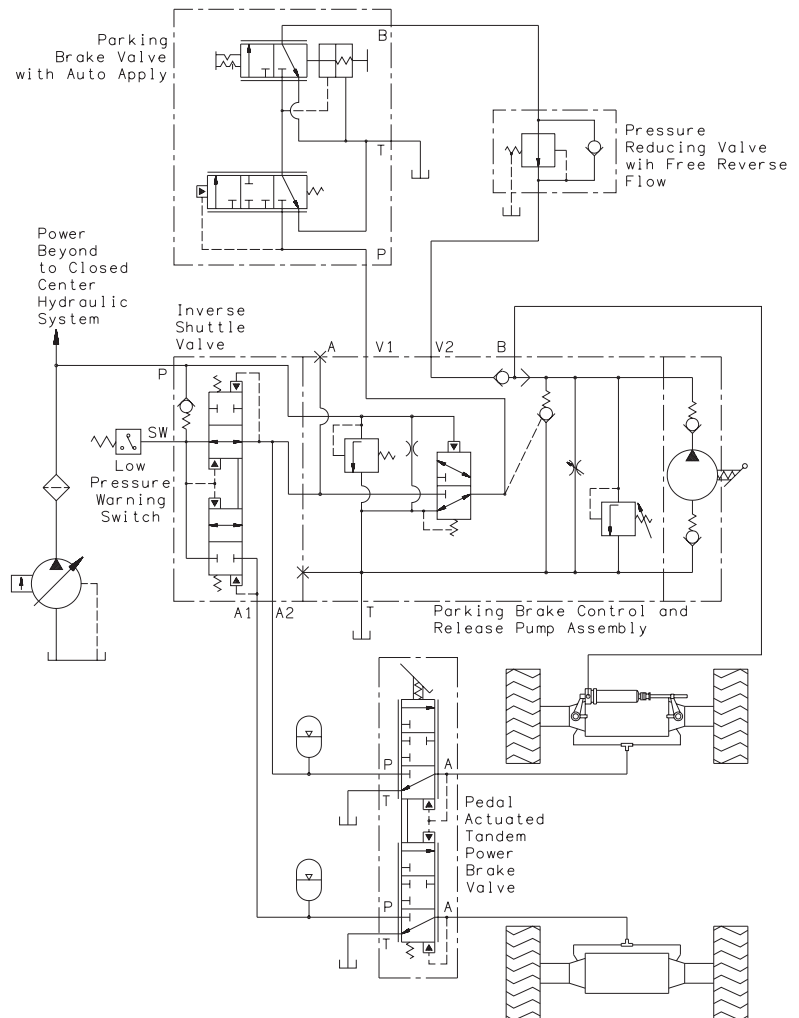
Ingersoll-Rand's Mining Jumbo maxi-HJ2 drilling machine used in underground mining relies on two braking systems — one for service and one for emergency-failsafe/park braking. The HJ2 has joystick-controlled full parallel boom and guide positioning with 270° rollover to reduce setup time for face drilling. Guide indexing to 90° permits roof and cross-cut drilling.

The service braking system is operated using a foot pedal, which controls power actuation to internal wet-disc, hydraulically-applied, axle-mounted brakes. Tandem circuitry allows independent boom-end and engine-end axle braking. Nitrogen-charged accumulators provide reserve power for multiple power-off stops.

An enclosed wet-disc, spring-applied, hydraulically released brake mounted in each axle provides failsafe (emergency) and park braking. The brakes are activated automatically with a loss of brake system pressure or manually by the operator.

At the center of the system schematic, an inverse shuttle valve interfaces with a parking brake control manifold and release pump assembly via subplate mounting. The inverse shuttle valve supplies two accumulators from a single closed-center hydraulic energy source. An integral check valve prevents backflow of the accumulator charge should the energy source fail. The low-pressure switch alerts the operator of a decay in accumulator pressure, which could cause an unsafe operating condition.

The park brake control manifold directs fluid within the hydraulic brake system. An integral hand-operated pump and relief valve assembly allows the operator to manually release or re-engage the equipment's spring applied/hydraulically released brakes without energizing the equipment.



applications call for special-purpose brakes — to maintain tension, for example. Tension brakes exert drag on a system to maintain tension. Typical applications include a web of paper, cloth, or other material as it unrolls from a spool. If tension in the web stays constant, drag decreases as the diameter of material remaining on the spool decreases. Figure 1 shows a setup that decreases pressure applied to the brake as material unrolls, which keeps tension in the web constant. Brakes such as these are specified according to required torque and thermal characteristics.

Spring-applied brakes that use hydraulic or pneumatic actuation for release are also used in industrial applications. These generally are selected based on torque capacity with little regard to thermal characteristics. This is because they usually are used to hold a stationary load. They also can be used as a failsafe brake to stop and hold a machine member when system hydraulic or pneumatic pressure is lost.

Mobile selection

Selection of a brake for mobile applications must consider terrain over which the vehicle travels. For instance, a vehicle descending a hill requires more braking power than one moving over level ground. Furthermore, ground conditions can vary widely from hard-packed surfaces to soft mud or any combination in between. The designer, therefore, must understand the vehicle operating conditions and consider worst-case conditions for brake system design.

Vehicle brakes can be mounted within the driveline or at individual wheels with hydraulic, pneumatic, or mechanical actuation. Vehicle design and operating requirements generally dictate which type is most suitable for an application.

For a brake mounted within the vehicle driveline, and assuming a ground coefficient of 1, required torque of the brake can be calculated:

$$T_B = r_T \times W_V \times (F_d + \sin\theta) / R_G,$$

where:

$$T_B = \text{required torque of brake, lb-ft}$$

- r_T = radius of static loaded tire, ft
- W_V = gross vehicle weight, lb
- F_d = deceleration factor (alg)
- θ = angle of decline
- R_G = gear ratio.

Similarly, assuming a ground coefficient of 1, when brakes are wheel-mounted with no gear reduction between the brake and the ground, the denominator of the equation becomes the number of brakes used instead of the gear ratio.

Note that when braking on level surfaces, $\sin\theta$ is 0, effectively removing the grade factor from the calculation. After calculating torque, diameter of the brake disc, size of the brake caliper and line pressure must be determined. These factors often are dictated by the application. Disc diameter may be specified based on the maximum diameter that will fit into the allotted space. Torque developed by each brake is a function of fluid pressure, number and size of actuating pistons, size of calipers, and coefficient of friction between calipers and the disk — 0.35 is a common value. Information necessary to specify a brake for an application is provided in manufacturers' catalogs.

Heat dissipation

More than one caliper per side can be installed on a disc to increase braking torque without increasing the envelope substantially. Keep in mind, however, that increasing the number brakes per surface increases heat generation. Thermal characteristics also are affected by surface speed of the disc relative to the brake caliper and kinetic energy of each stop, which is calculated by using:

$$E_K = W_V \times v^2 / 2g,$$

where:

- E_K = kinetic energy, ft-lb
- v = velocity of vehicle, ft/sec².

Brakes applied by springs and released via hydraulic or pneumatic pressure are widely used for static conditions, usually a vehicle parking brake. To calculate holding torque of a wheel-end brake on a grade, use:

$$T_H = W_V \times r_T \times \sin\theta / N_B,$$

where:

- T_H = holding torque of brake, lb-ft
- N_B = number of brakes.

Note that for a level surface $\sin\theta$ is 0, so no torque would be required. Obviously, a minimum holding torque would be desirable to keep a vehicle stationary on a level surface. Also note that this equation can be used for a brake mounted within the driveline by using gear ratio instead of the number of brakes in the denominator.

Braking ratio

Finally, weight transfer during deceleration on level, inclining, and declining surfaces must be considered. This may result in greater brake capacity at, say, the front wheels than at the rear. Historically, larger brakes were located at the wheels supporting the greatest load, which, in practice, were usually the rear wheels. However, under the right conditions, hard braking can cause rear wheels to actually leave the ground, meaning that all braking can occur at the front wheels.

Brake ratio is a factor that takes into account uneven effects of braking. Brake ratio should be considered to ensure applying the proper torque to front and back wheels. As might be expected, though, brake ratio can vary with surface conditions. A variety of accessory devices can be installed in the brake control system to adjust brake ratio accordingly.

Among the newest brake technologies are anti-lock braking systems that keep tires from skidding. A non-rotating tire on a moving vehicle contributes less directional control for the vehicle than a runner on a sled. Anti-skid systems provide maximum deceleration while ensuring that no matter how much pressure is applied to the system, a tire will not skid until its ground speed has decelerated to 5 mph or less.

HP

MICO, Incorporated

1911 Lee Boulevard (Zip Code 56003-2507)
 P.O. Box 8118 / North Mankato, MN U.S.A. 56002-8118
 ☎ 507.625.6426 Facsimile 507.625.3212

MICO West Division

701 East Francis Street (Zip Code 91761-5514)
 P.O. Box 9058 / Ontario, CA U.S.A. 91762-9058
 ☎ 909.947.4077 Facsimile 909.947.6054

Web Site: <http://www.mico.com>