Clutches and Brakes Seize the Market for Low-Cost Load Control

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A wide variety of motion control applications require brakes and clutches for holding, stopping, indexing, jogging, or releasing a mechanical load. When the prime mover is an electric motor, it can often perform a dual role, that is, not only accelerate the load, but also bring it to a preprogrammed position and hold it there. Servomotors and step motors are excellent components for doing this job, but they usually cost 10 to 15 times more than comparable mechanical and electromechanical brakes and clutches. Only those applications that require relatively expensive equipment and extremely high duty cycles, such as mail sorters, can justify the cost of these motors. For most other jobs, clutches and brakes are the optimum choice.

Clutches and brakes can be used with any type of motor or no motor at all. They come in a variety of sizes, selectively grouped in torque and speed between a range of 3 to 5000 lb-in. and 150 to over 20,000 rpm. Their specifications are spread over four modes of operation: start, index, slip, and hold. The start and slip modes are rated exclusively for clutches, the hold mode for brakes, and the index mode for both clutches and brakes. Clutches and brakes come in many designs but this article will focus on two key technologies, wrap spring and electromagnetic. They have unique specifications that make one type more suitable for a specific application than the other.

Electromechanical brakes come in two types, power on, and power off. The power-on type engages the brake when power is applied to the holding coil. Power off, on the other hand, releases the brake when power is applied. In the second case, a spring holds the brake closed or engaged (without power) during normal operation. This type is used more frequently because the brake holds the load in a fixed position in the event of an unanticipated power failure. The power most component manufacturers use to engage or disengage the clutch is typically 12 to 24 Vdc. Other voltages, including ac, however, may be ordered.

Clutches and brakes are often selected for one or more dynamic and static characteristics including torque, speed, accuracy and as many as thirteen other specifications. Although these specifications apply to both wrap spring and electromechanical clutches and brakes, about half of these specifications apply more aptly to one type, and the other half to the other type.

Wrap Springs

Clutches and brakes that use wrap springs tend to excel in performance for six of the characteristics; torque capacity, low power, positive engagement, stopping accuracy, and pneumatic or mechanical actuation. They are also most suitable for single revolution operation, and are on an even par with electromechanical clutches and brakes for rapid cycling capability. On the down side, their one most limiting characteristic is their speed that tops out at about 1750 rpm.

Wrap spring clutches and brakes are composed of three basic parts, an input hub, a wrap (coil) spring, and an output hub. These clutches come in overrunning, start-stop (random positioning), and single revolution types. A fourth type is the clutch-brake combination which uses two wrap springs. In the basic form of an overrunning clutch, when the input hub rotates, the spring wraps down to engage the two hubs. (Fig. 1.) When the input stops or reverses, the spring unwraps to release the output hub, and lets the load overrun. These clutches also are used for one-way indexing and backstopping functions.

The overrunning clutch may be modified to become a start-stop clutch by adding a control tang to the spring. (Fig. 2.) It lets the clutch engage and then disengage the load when the tang locks into position with the stop collar. After it's disengaged, the load coasts freely from the continuously running input.

A single-revolution clutch can be made by securing a second tang to the output hub. (Fig. 3.) When the control tang engages, the output hub cannot overrun because it is secured to the spring. Because most single-revolution clutches can stop only about 10% of their starting load capacity, make certain the selected clutch has sufficient braking torque capacity for the job.

Wrap spring clutch/brake combinations use two control tangs to hold open either the clutch or brake spring. (Fig. 4.) When the clutch and brake control tangs rotate with the input hub, the clutch spring positively engages the input hub and the output shaft. When the stop collar locks the brake control tang, the brake spring wraps down to engage the output shaft to the stationary brake hub. Simultaneously, the clutch spring unwraps slightly, and lets the input hub rotate freely.

Wrap spring clutches and brakes perform hundreds of simple motion processes that can be controlled through overrunning, start-stop, and single revolution functions. The torque capacity of a spring wrap clutch or brake is a direct function of the diameter of the hub and the tensile strength of the spring. That is, it will not slip, but rather supply the torque demanded up to the mechanical limitations of the spring. When the spring is allowed to wrap down to grip the hubs, the output hub typically accelerates to the input rpm in 0.003 sec., and the output in 0.0015 sec. The dynamic torque of acceleration or deceleration is proportional to the product of rpm and the load inertia, divided by the acceleration time. This implies that spring clutches and brakes are inertia sensitive, that is, the more inertia, the higher the dynamic torque. In addition, the torque demand on the spring clutch equals the system frictional torque of the load plus the dynamic torque of acceleration.

When approaching the stop position of the cycle, enough energy must be available in the rotating mass of the load to let the spring release its grip on the input hub. This means that when there is a large frictional load, or a torque demand when the load comes up to the top of a cam, sufficient energy must be available in the rotating mass to open the spring. Without sufficient energy, the input hub could wear excessively and generate noise.

Electromagnetic Clutches

Electromagnetic clutches tend to excel in performance for another six of the 16 possible characteristics; random start/stop, power-on and power-off braking, soft start/stop, bi-directional rotation, and speeds exceeding 1750 rpm. A simple electromagnetic clutch is a device that connects a motor to a load. (Fig. 5.) Generally, the motor shaft is pinned or keyed to the clutch rotor-shaft assembly bore (input) with the load connected to the armature (output) of the clutch with a pulley or a gear. Before the coil energizes, the armature assembly does not couple, so it cannot rotate with the input rotor shaft. When the coil energizes, however, the rotor shaft assembly becomes part of an electromagnet, attracts the armature plate, engages this with the rotor assembly, and drives the load. When the coil de-energizes, the two elements no longer attract and a spring within the armature assembly separates them. The motor shaft and load disconnect so the load cannot be driven. The clutch lets the motor run while the load idles, which decreases cycle times and yields better overall system efficiency.

Clutch couplings also connect two parallel shafts with pulleys, gears, or sheaves. (Fig. 6) Although an anti-rotation tab or flange prevents the field (electromagnet) from rotating, the rotor and armature assembly mount on a single shaft with the rotor secured to the shaft. The armature mounts through bearings and rotates freely. When the coil energizes, the armature engages the friction surface of the rotor and drives the load. Electromagnetic clutch couplings provide the same efficient, electrically switchable link between a motor and a load for in-line shafts. Here again, an anti-rotation tab or flange prevents the field assembly from rotating, and the rotor and armature assembly securely mount on opposing in-line shafts. When the coil energizes, the armature engages the friction surface of the rotor, couples the two in-line shafts, and drives the load.

Power-on brakes operate under the same principle as the clutch, but with only a single rotating component, the armature assembly. (Fig. 7.) The brake is generally positioned on the load shaft with the armature assembly secured to the shaft and the field assembly is mounted to a non-rotating component or bulkhead. Before the coil energizes, the armature assembly rotates freely. When energized, the field assembly becomes an electromagnet, attracts the armature plate, and stops the load.

Power-off, spring-set brakes operate under a slightly different principle (Fig. 8). Compression springs within the field assembly apply the braking force. In the normal power-off mode, the springs apply pressure to the fixed (non-rotating) armature plate, which in turn applies pressure to the rotor. The rotor can float back and forth under the applied pressure, depending on the state of the coil. A spline or hex couples it to the load shaft through a hub. Some rotors are suspended between two diaphragm-like springs to reach the floating state.

Power-off, permanent-magnet brakes use the attractive force of a permanent magnet to create the braking action, while the electromagnet negates this force and lets the load rotate (Fig. 9). In normal power-off mode, the permanent magnet in the fixed field assembly creates an attractive force on the armature assembly, which is attached to the load shaft with setscrews or pins to stop or hold the load. When the coil energizes, the electromagnet forms an opposing magnetic force to the permanent magnet and lets the armature assembly rotate freely (no brake).

Tooth Brakes and Clutches

Clutches and clutch couplings provide an efficient, positive, switchable link between a motor and load on in-line or parallel shafts when used in either static or low-speed engagement applications (Fig. 10). A fixed flange prevents the field assembly from rotating, and the rotor generally attaches to the input shaft. The armature assembly mounts securely to either an in-line load shaft or a parallel shaft with pulleys or gears. When the coil energizes, the teeth in the armature positively engage the teeth in the rotor, which then couples the two in-line or parallel shafts and drives the load.

Tooth brakes provide an efficient, positive, switchable means of either holding a load or decelerating a load from a slow speed, generally 20 rpm or less. Using the same principle as the tooth clutch, these brakes can be used to effectively hold a load in position. They come in power-on and power-off types and are ideal for applications requiring very high torque in tight places.

Multi-Disc Brakes and Clutches

Multiple disc clutches provide a smooth, efficient, switchable link between a motor and load on in-line or parallel shafts (Fig. 11). Like the other components, an anti-rotation tab on the flange prevents the field from rotating, and the rotor securely mounts on the drive shaft. The armature assembly is then mounted either directly on an opposing in-line shaft or indirectly on a parallel shaft with gears or pulleys. When the coil energizes, the armature engages the friction surface of the rotor which further engages the multiple discs within the assembly until full torque is reached, couples the two in-line or parallel shafts, and drives the load.

Multiple disc brakes offer the same smooth, efficient operation as a standard braking device. Here, the rotor component is eliminated and the electromagnet engages a static field assembly plus a rotating armature assembly to accomplish braking. These types of brakes provide high torque in a compact package, and are intended primarily for custom applications in the aerospace industries.

Selecting a Spring Wrap Clutch/Brake

Wrap spring clutches and brakes are prepackaged, pre-assembled units that are surprisingly easy to select and install. It takes only three steps: Determine the clutch or brake function, determine the size, and verify the design considerations. The selection process assumes that the diameter of the shaft at the clutch or clutch/brake location has been designed with good machine practice. For most applications, this process determines the proper size product. When the performance requirements of an application are marginally within the capabilities of a product, consider using the next larger size. In cases where the required load/speed performance data are known and unit size is uncertain, contact the manufacturer for a more in-depth technical selection process guide that will help you review all necessary aspects of your application.

Step One: Determine the function

These units can perform three functions, overrunning, start-stop, and single revolution. Determine the function that provides the best control for the application. Select the series that best fits the application requirements from the manufacturer's selection charts.

Step Two: Determine the Size

First, determine the maximum clutch or brake speed and the shaft diameter for mounting the wrap spring. A wrap spring clutch engages almost instantly, and because spring wrap increases with load, the unit must be sized properly to ensure that it is correct for the application. If there is any uncertainty regarding the correct unit size, use the technical selection process guide from the manufacturer mentioned above. Select the correct wrap spring unit by locating the appropriate speed and shaft diameter points on a chart that correlates to the model that best suits your application. For applications that require higher speed or larger diameter shafts than those shown, the manufacturer will offer additional assistance.

Step Three: Verify the Design Function Considerations

After selecting the appropriate series and model size, review the design considerations. A complete checklist of these and other options are detailed in the "How to Order" section of the manufacturer's catalog for each series.

Selecting Friction Brakes and Clutches

It may be necessary to consider clutch or brake inertia and engagement time in calculating load acceleration for some applications. When the inertia or engagement time of the clutch or brake initially selected represents more than 10% of the load inertia or acceleration time, use the *inertia-time* equation to solve for acceleration time. Use an inertia value equal to the sum of the load inertia and the clutch or brake inertia. Then verify that the sum of the acceleration and clutch or brake engagement time is still within the required acceleration time for the application.

Brake Selection

Step One: Determine if the application requires a static (holding) or a dynamic (stopping) brake.

Step Two: For static brake applications, determine the required static torque to hold the load under worst-case conditions, including system drag. Skip to Step Five.

Step Three: For dynamic braking applications with a specific stopping time requirement, first calculate the dynamic torque (T_D) necessary to decelerate the load using the inertia-time equation:

$$T_D = (0.104(I\omega)/t) - D$$

Where: I = total system inertia, lb-in.-sec^2
ω = shaft speed. rpm
t = time to zero, sec
D= load drag, lb-in.

Multiply by 1.25 to convert to static torque. Go to Step Five.

Step Four: For dynamic braking applications that require the ability to only stall a load, calculate the appropriate static torque (Ts) using the horsepower-rpm equation:

$$Ts = (1.25)(63000)(Pk)/\omega$$

Where: P = horsepower, hp
k = service factor
ω = speed, rpm

Step Five: Select a brake model from the manufacturers catalog with a static torque rating greater than the required torque. Verify that the selected brake fits into the available application envelope and mounting configuration.

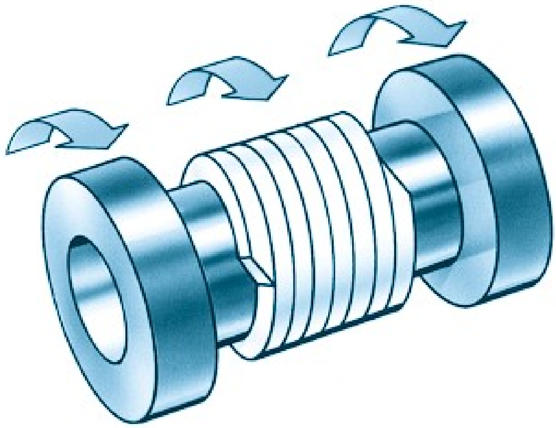


Figure #1, Overrunning Clutch

The wrap spring clutch is an overrunning clutch. When the input hub rotates, the spring wraps down to engage the two hubs. When the input stops or reverses, the spring relaxes, and releases the output hub.

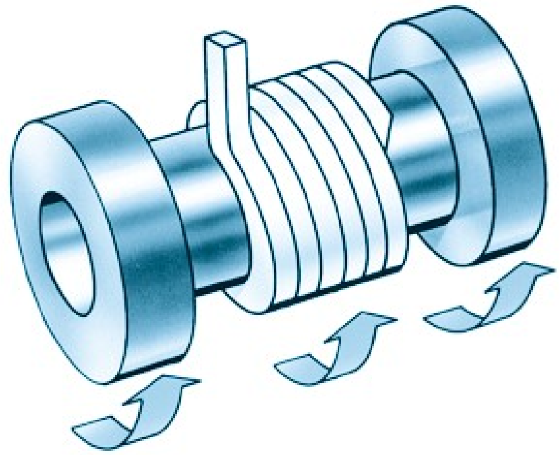


Figure #2, Start-Stop Clutch

A control tang lets the clutch engage, then disengage the load when the control tang locks in position. When disengaged, the load coasts freely.

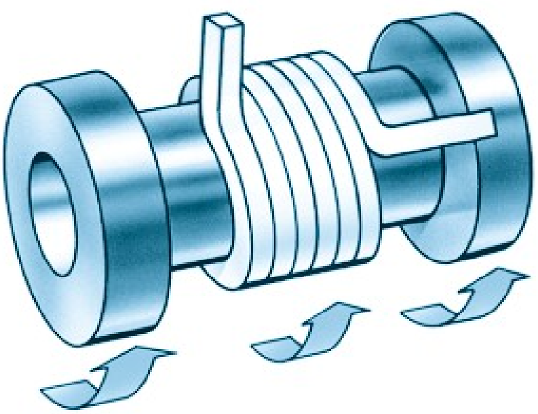


Figure #3, Single Revolution Clutch

This clutch has a second tang secured to the output hub. When the tang engages, the output hub cannot overrun.

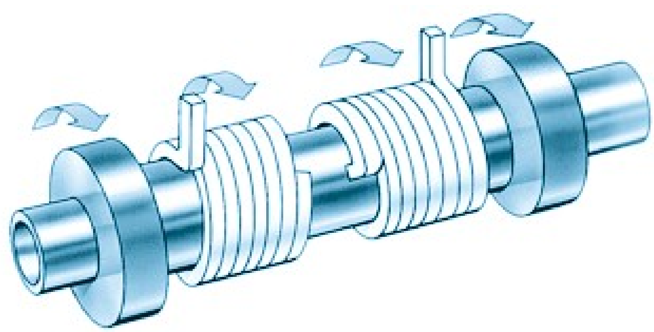


Figure #4, Combination Clutch/Brake

A brake/clutch uses two tangs to hold either the clutch or brake spring open. When both tangs rotate with the input hub, the clutch spring engages the hub and the output shaft. When the stop collar locks the brake control tang, the brake spring wraps down and engages the output shaft to the stationary brake hub, and the clutch spring unwraps a little, which lets the input hub rotate freely.

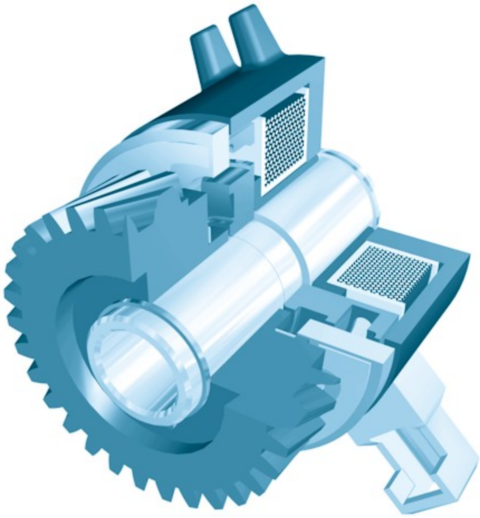


Figure #5, Electromagnetic Clutch

The armature is normally decoupled and free to run until the coil energizes. When the magnetic field is generated, the rotor-shaft assembly attracts the armature plate, engages with the rotor assembly, and drives the load.

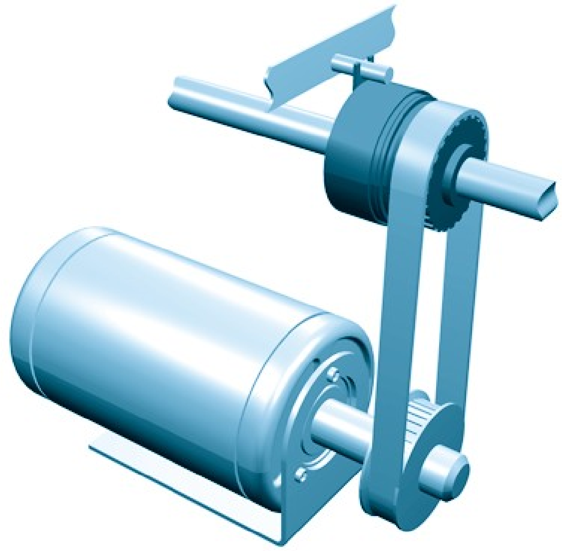


Figure #6, Electromagnetic Clutches and Clutch Couplings

Clutches couple two parallel shafts with pulleys, gears, or sheaves. An anti-rotation tab prevents the assembly from rotating until the coil energizes, thus engaging the armature with the friction material and driving the load.

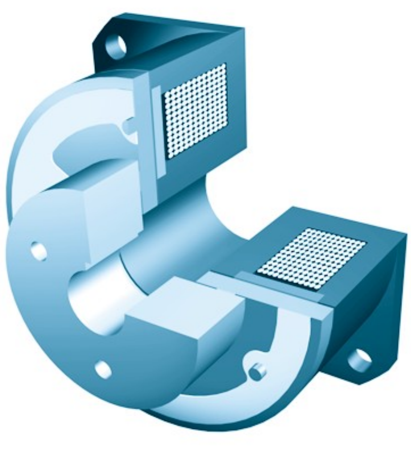
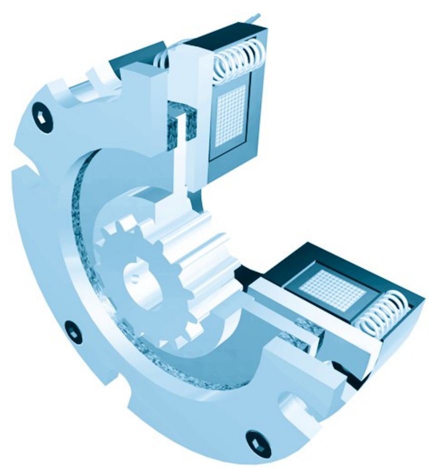


Figure #7, Power-On Electromagnetic Brake

The armature assembly rotates freely until the coil energizes, attracts the armature plate, and brakes the load.



Fi**gure #8, Power-Off Electromagnetic Spring-Set Brake**

Compression springs normally apply the braking force. In power-off mode, the springs apply pressure to the armature plate, which, in turn, applies pressure to the rotor. When the coil energizes, the brake spline decouples from the load shaft and the load rotates freely.

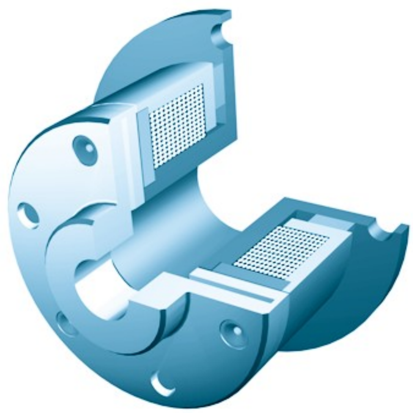


Figure #9, Power-Off Electromagnetic

Permanent Magnet BrakeThe permanent magnet provides the normal braking force. When the electromagnet energizes, its field opposes the permanent magnet’s field, which then allows the armature assembly to rotate freely.

Figure #10, Tooth Brakes and Clutches

Tooth clutches link a motor and a load on in-line or parallel shafts. A fixed flange prevents the electromagnet from rotating. When the coil energizes, the teeth on the armature engage with the teeth on the rotor, couple the shafts, and drive the load.

Figure #11, Multi Disc Brakes and Clutches

Disc clutches also link a motor and a load on in-line or parallel shafts. Similarly,a fixed flange prevents the electromagnet from rotating until the coil energizes. When energized, the armature engages the friction surface of the rotor, which in turn, engages the multiple discs until full torque is achieved. Then the two shafts couple and drive the load.