

## Selecting a Wrap Spring Clutch/Brake for Optimal Performance and Long Service Life

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Clutches and brakes are among the most critical elements of many motion control systems. The two most widely used types of clutches are electro mechanical friction and wrapped spring. When selecting a clutch, electro mechanical friction types usually come to mind first, but the frequently overlooked wrap-spring clutch might be a better choice because of its unique characteristics. The main unique characteristic of the wrap spring clutches are the package size vs. the amount of static torque that can be transmitted. An electro mechanical friction clutch or brake to transmit 125 lb-in of torque the outside diameter of the unit is 3.27 inches in diameter. The wrap spring equivalent torque rating the outside diameter of the spring hub on the clutch is only .743 inches in diameter.

A machine that is intended to move a load to a particular position and hold it within a few thousandths of an inch requires some type of brake. Electro mechanical friction brakes are usually selected to handle this kind of job and are available from many manufacturers. However, a wrap-spring clutch usually is less expensive and can be used in applications that do not demand extremely high positioning accuracy. Moreover, in a few certain cases, a wrap-spring clutch can be modified easily to function similar to a brake by attaching one of its hubs to a stationary frame in the application (Fig 1). Lastly, certain electro mechanical friction clutch/brake combinations also can be used, but they tend to have less braking capacity for a comparable size and require external power to function. For example, a ball screw assembly moving a load in the vertical direction requires a power-off friction electric brake that activates during a power failure to prevent it from falling.

Overrunning type wrap-spring clutches are usually a better choice for certain noncritical applications where a machine moves a load without regard to its final stopping position, such as a conveyor feed mechanism. Also, wrap-spring clutch/brakes are best suited and probably most widely used for applications that require multiple starts and stops during a single revolution. Some examples are printing presses, postage machines, conveyors, packaging machines, and food and material processing equipment (Graphic #1).

### Spring Wrap Clutches and Clutch/Brakes

The drive function needs to be carefully reviewed to select the correct clutch for an application. Wrap spring clutches are unidirectional as compared to an electro mechanical friction clutch or brake that is bi-directional. Compared to an electro mechanical friction brake, a wrap-spring

clutch doesn't require a coil and a friction plate with an expensive friction material. The unit transmits torque through the interference between the drive spring inside diameter and the outside diameters of the input and output hubs. The drive spring is a helical wound spring transmitting torque only in one direction. The way the spring is coiled when it is wound determines the rotation. There needs to be some type of input drive to the clutch for the clutch to operate. When the clutch is rotated in the direction the drive spring is wound it will connect the input and output hubs together transmitting the clutch rated torque. The PSI series is the basic principles of the wrap spring clutches (Graphic #1). There are 3 basic model types, Model "O", "SS" or "S". The Model "O" has no control tangs to engage or disengage the spring. The Model "O" has a dust cover over the spring to keep debris off of the spring. The Model "SS" has an out tang to control the engaging and disengaging of the spring. The Model "S" has two control tangs, an out tang and an axial or down tang to engage and disengage. The axial or down tang controls the output positioning and braking capacity of the clutch.

The Model "O" spring is basically a one-way clutch and used to keep an output load from backing. To allow the clutch to be engaged and disengaged a control tang needs to be added to the drive spring and a stop collar added onto the clutch body (Graphic #2). The control tang of the drive spring nests into a slot on the stop collar. The stop collar now allows the clutch to be engaged and disengaged. The tang on the drive spring is called a "Model SS" which is a random start/stop clutch. The drive spring is not connected to the output hub so the output will stop at the same position but with no positional accuracy. Using the same principles an additional tang can be added to the drive spring. The secondary tang is usually anchored to the output hub. The secondary tang is usually a down tang or axial tang. The 2 tangs on the drive spring are called a "Model S" which is a single revolution clutch. The drive spring is now coupled to the output hub giving you positioning accuracy of  $\pm 20$  degrees. The Model "S" also gives 10 % braking capacity to stop the output shaft. To engage the Model "SS" or "S" clutch (Graphic #2) a mechanical stop must be added to the drive system. The mechanical stop is usually supplied by the end user. The mechanical stops are some times manual devices or electric depending on the applications. The mechanical stop needs to contact the stop lug on the stop collar. When the stop collar lug contacts the mechanical stop the clutch will disengage. To engage the clutch the mechanical stop needs to be removed allowing the drive spring to wrap down onto the output hub. The spring unwraps and releases the output hub while the input hub continues rotating. If the braking torque exceeds the 10% and you need positional stopping accuracy, the next product to consider would be the wrap spring clutch/brake series.

A clutch/brake (CB, Graphic # 3) typically combines the elements and functions of the clutch and the brake. The clutch/brake is a package product including the clutching and braking function plus the actuation system. There are 2 different models of clutch/brakes. There are the Standard CB and Super CB models. The Standard CB's are utilized where the normal cycle life requirement is less than 8 to 10 million cycles. When the cycle life requirements are over 8 to 10 million cycles the Super CB should be consider. The Super CB gives 3 to 5 times the life compared to the Standard CB. The CB Super has additional features to enhance the life. These units are interchangeable so upgrading to a Super can be at any time.

The clutch/brake can transmit the same drive and braking torque depending on the application. The additional brake spring in the clutch/brake allows this unit to have the same torque capacity as the drive. With any clutch there needs to be an input drive to couple the input of the clutch. The input drive is usually a timing belt pulley, gear or sprocket attachment. The input of the clutch needs to rotate for the clutch/brake to function. The basic clutch/brake consists of an input hub, clutch and a brake spring with control tangs anchored to the output shaft and a stationary brake hub bolted to a plate. There are also 2 additional springs in the clutch/brake the anti-overflow and the anti-back spring. The clutch/brake also has an actuator and an AC or DC solenoid (optional pneumatic cylinder) to engage and disengage the unit.

When the stop collar is against the actuator the drive spring is unwound off of the input hub which in turn wraps down the brake spring (Graphic #4). The unwinding of the drive spring and the wrapping down of the brake spring is controlled by the stop collar. The drive spring is interference fit onto the input and output hub. The drive spring and brake spring both have an in out tang and a down tang. The down tangs of both springs are anchored to the output hub. The drive spring is interference fit on the input and output hub. The brake spring is a clearance fit onto the output and brake hub. The out tangs of the drive and brake spring nest into a slot into the stop collar. The stop collar engages and disengages the drive and brake spring. The brake hub is anchored to the clutch plate that is anchored to a stationary frame of the machine. The anti-overflow spring keeps in the input and output hubs in sync. The anti-overflow spring is used on over hauling load applications like a crank arm to keep the input and output speeds at the same rpm. Without the anti-overflow spring the input could speed up faster than the output changing the output timing between the input and output hubs. The anti-back spring is used to keep the output in place when the brake spring is wrapped down. The brake spring and anti-overflow spring combination gives the clutch/brake the  $\pm 0.5^\circ$  stopping accuracy.

The clutch spring wraps down when the solenoid is energized and the actuator is pulled away from the stop collar. The drive spring out tang that is in the stop collar also controls the brake spring. When the drive spring wraps down onto the input hub at the same time the brake spring is unwinding off of the brake hub allow the output to rotate. Depending on the application the input hub can free wheel for long periods of time. When the clutch needs to make a single or multiple revolutions the solenoid is energized which pulls back the actuator. This causes the drive spring to wrap down onto the output shaft. At the same time the brake spring is released which disengages the brake. The clutch/brake will make a single revolution, or multiple revolutions depending on the length of time the solenoid is energized. The stop collar can have up to 24 stops and give you  $15^\circ$  indexing per stop. The numbers of stops is dependent on the speed of the application. When power is removed from the solenoid the clutch will continue to rotate until the stop collar contacts the actuator. When the stop collar lug contacts the actuator the drive spring unwinds and the brake spring wraps down. The positional accuracy of the clutch/brake is  $\pm 0.5$  degrees. The  $\pm 0.5$  degree is not accumulative from cycle to cycle. An example of a motion system using a wrap-spring clutch/brake is shown in Graphic #5.

Friction clutches and wrap-spring clutches and brakes serve the same purpose, but perform differently under various load conditions. For example, when torque must be applied in both directions, the friction clutch should be considered. Typically, wrap-spring clutches are unidirectional, since the spring wraps down and grips the hub in one direction and unwraps and releases the hub in the opposite direction.

Motion systems that require a soft start normally use friction clutches since the friction can be gradually reduced or increased by varying the voltage across the coil. However, when the load needs to come into synch rapidly, say, within a predictable time or travel, the wrap spring clutch is a better choice.

When the slip mode is not allowed, a wrap spring device should be considered. A wrap spring clutch or brake will not slip after the spring wraps down and locks the hubs together, but a friction device slips under certain conditions.

Wrap spring devices are quite cost effective due to their simple construction. When used properly, they are maintenance free and do not require periodic parts replacement or lubrication. They are easy to install and have long service life.

A typical clutch/brake brings the load up to the input speed in about 3 milliseconds and stops the load in 1.5 milliseconds. These times are nearly constant and do not depend on inertia or frictional load as long as the torque capacity is not exceeded. The starting and stopping times of a frictional clutch or brake depend extensively on the inertial and frictional load (Fig. 6). In many applications, this factor is extremely important. For example, when a printing press operates, the weight of the paper roll diminishes as the paper is drawn. The inertia drops as the weight diminishes, but the linear start and stop positions of the paper must remain unchanged as the paper is consumed. Consider another long-term factor: Over time, the bearings wear and the friction increases. Again, wrap-spring devices are better equipped to maintain accuracy under these varying conditions.

### **Selecting Wrap Spring Clutch/Brake**

Three basic steps are required to select wrap-spring clutch/brakes: determine the clutch/brake function, determine the clutch/brake size, and then verify the design considerations. First, a clutch/brake assembly must be selected based on load and speed requirements. Secondly, a standard-diameter shaft should be selected because of the physical size limitations of the clutch/brakes.

#### **Step 1: Determine the required function.**

Wrap-spring clutches and clutch brakes are most appropriate for applications where the accuracy of the starting and stopping positions must be maintained while the motor continuously rotates. The stopping accuracy can be expected to be within +/- 0.5 degree on the clutch brake models.

## Step 2: Determine the size

A quick way to select the correct clutch or clutch brake model is from a manufacturer's catalog is to consult an RPM vs. Shaft Diameter selection chart (see Fig. 7). Start with the shaft diameter in the Bore Size column and shaft speed expressed in RPM. Select the correct model from the Clutch Size model while staying within the gray area. If the diameter of the shaft is outside of the gray area for the desired RPM, and no particular requirement for the shaft diameter is specified, consider selecting a shaft that would fit the chart selection criterion. However if the shaft is required to be larger or smaller than the selection chart suggests, consult the clutch/brake manufacturer for a possible custom device.

The following calculations verify that the clutch has sufficient torque to start the load, and the load and shaft have enough inertia to activate the stop spring of the clutch/brake.

Calculate the inertia,  $WR^2$ , of all rotating components, such as shafts, drums, pulleys, and so forth. Consult a reference table listing inertia of steel shafting per inch of their length of thickness (if not found in clutch/brake catalog, obtain from manufacturer). For materials other than steel use conversion multipliers usually included with the listing.

For hollow components, calculate the inertia of a solid component (O.D.); calculate the inertia of the hollow area as if it were a shaft (I.D.). Then subtract the I.D. inertia from the O.D. inertia and multiply the per inch number by the length or thickness of the component.

Determine the preliminary clutch/brake torque requirement to perform the function determined in step 1.

$$T = (WR^2 \times S)/(3700 \times t) - T_f$$

Where:

T = torque required to wrap down the spring, in.-lb

$WR^2$  = Load inertia determined above, lb-in.<sup>2</sup>

S = Shaft speed at clutch/brake, RPM

t = time to disengage (0.0015 s when braking), seconds

$T_f$  = friction torque (torque required to overcome static friction), in.-lb

Consult the detailed product specifications and verify that the selected clutch/brake model exceeds the torque requirements.

From the same specification, find the unit inertia (inertia of the rotating component of the selected clutch/brake) and calculate the torque requirement more accurately by adding it to the load inertia.

$$T_t = [(WR^2_{LOAD} + WR^2_{UNIT})S]/(3700 \times t) - T_f$$

Where:

$T_t$  = total system torque, in.-lb

$WR^2_{LOAD}$  = load inertia, lb-in.<sup>2</sup>

$WR^2_{UNIT}$  = clutch/brake inertia, lb-in.<sup>2</sup>

S = shaft speed, RPM

$T_f$  = friction torque, in.-lb

The second aspect to verify is whether the load has enough inertia to fully engage the stop brake spring and disengage the clutch spring in order to accurately stop the load. The minimum inertia can be found as follows:

$$I = [(t) (T_c + T_o) (3700)]/S - I_c$$

Where:

I = minimum inertia required to fully engage the stop spring and disengage the clutch spring, lb-in.<sup>2</sup>

t = time, seconds

$T_c$  = torque specified to activate the selected clutch/brake, in.-lb

$T_o$  = drag torque, in.-lb

S = shaft speed, RPM

$I_c$  = inertia of the clutch/brake output side, lb-in.<sup>2</sup>

If the result is zero or negative, the overall system has enough inertia for stopping within the specified accuracy. When the result is positive, the springs will not wrap down and release properly. Additional inertia equal to or greater than the calculated minimum inertia should be added to the system.

Use the equation below to determine the maximum load inertia that a given clutch/brake model can handle without excessive wear or failure:

$$WR^2 = (T \times 3700 \times t)/S$$

Where:

T = clutch/brake torque, in.-lb

t = 0.0015 seconds

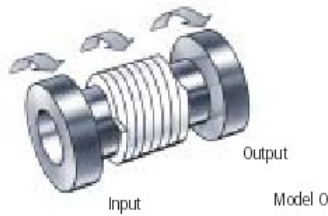
S = speed, RPM

### **Step 3: Verify the design considerations**

Manufacturers' data sheets and catalogs provide a detailed list of options to help build a complete product part number. In order to fully specify the clutch/brake, review the design considerations and make selections.

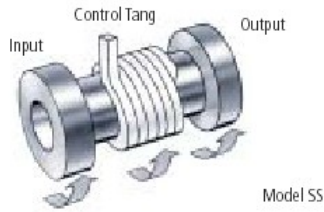
Choose clockwise or counter clockwise direction of rotation, and then select the stop collar. Stop collars with one or more stops (up to 24) sets either full or fractional rotation. Next, select the bore size. Finally, choose from the available activation methods, usually AC or DC solenoids (optional pneumatic). The most widely used solenoid voltage rating is 24 V dc, but other voltages often are available. Many clutch/brakes are offered in both standard-life and long-life configurations. Review each carefully, since they usually come with considerable cost and performance differences.

Product catalogs and web sites contain many tools that are helpful in the selection process. In addition, don't overlook the manufacturers' offer to provide extensive technical support and assistance in selecting a wrap spring clutch/brake for optimal performance and long service life.



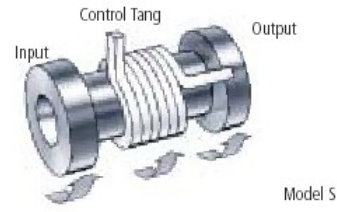
**Overrunning Clutch**

In its basic form, the wrap spring clutch operates as an overrunning clutch. When the input hub is rotated as shown, the spring wraps down to engage the two hubs. If the input is stopped or reversed, the spring unwraps to release the output hub, allowing the load to overrun. PSI Series overrunning clutches can also perform one-way indexing and backstopping functions.



**Start-Stop Clutch (Random Positioning)**

Modifying the basic PSI Series clutch with a control tang allows the clutch to engage and then disengage the load when the control tang is locked in position by the stop collar. Once disengaged, the load coasts freely from the continuously running input.

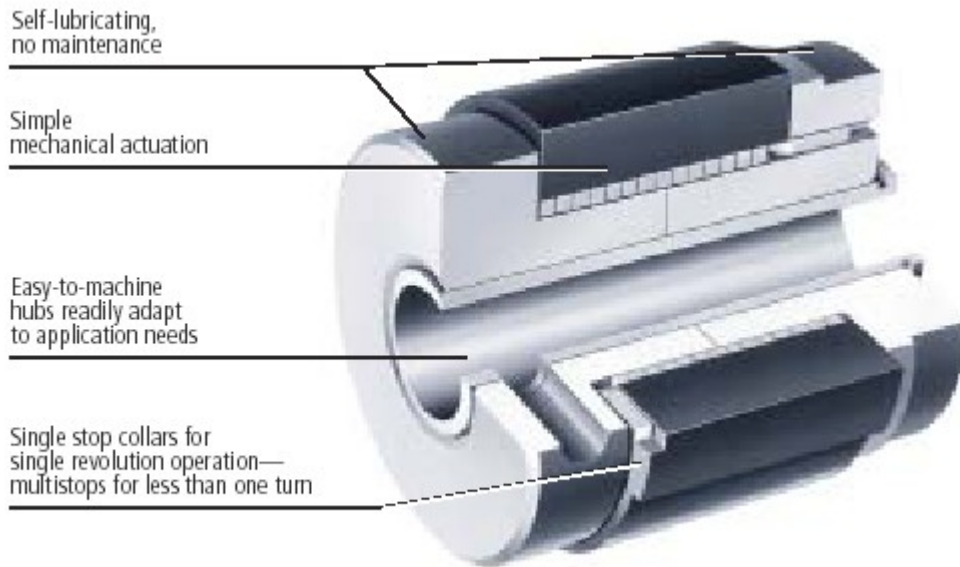


**Single Revolution Clutch**

A second tang, secured to the output hub, allows PSI Series clutches to perform single revolution functions. When the control tang is engaged, the output hub cannot overrun because it is secured to the spring. Single revolution PSI, SP and SAC Series clutches are capable of stopping only 10% of their starting load capacity. A CB Series unit is recommended where higher braking torque is required.

**Graphic #1 – Wrap Spring Design Configurations**

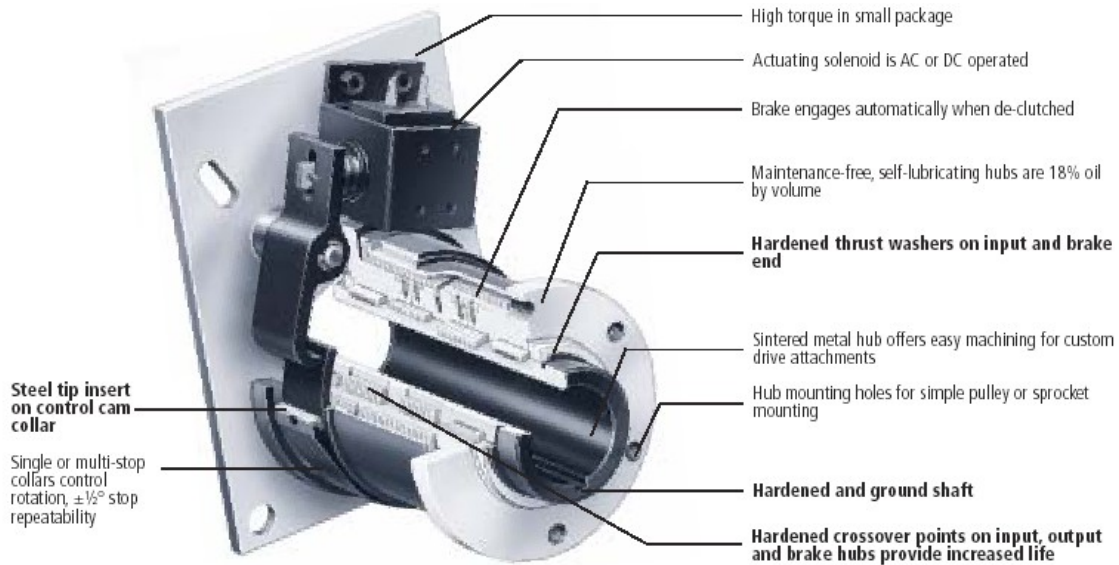
In its simplest configuration, the wrap spring clutch consist of an input hub, an output hub, drive spring and either a dust cover for the Model “O” or stop collar for Models “SS” and Model “S” (Graphic #2).



**Graphic #2 – Wrap Spring Clutch**

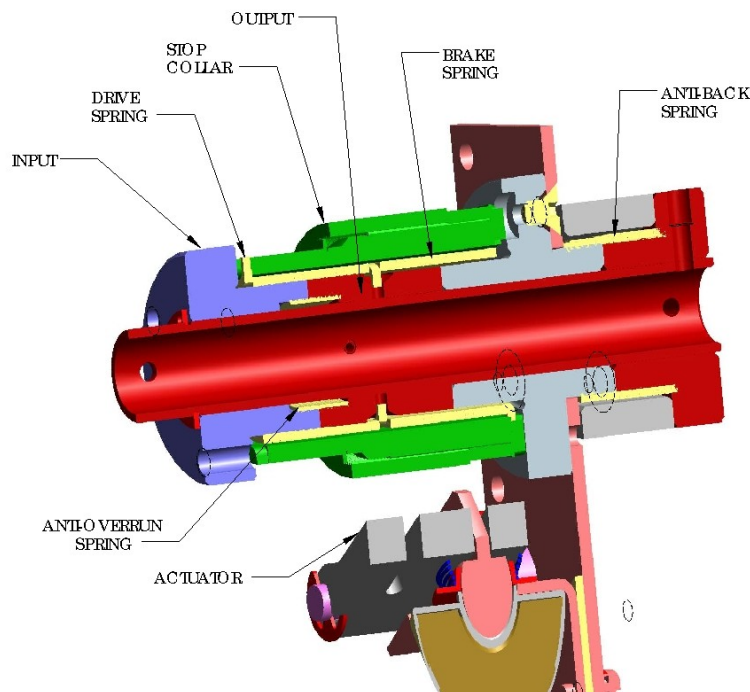
Complete PSI series with stop collar to engage and disengage the Model “SS” and Model “S” configurations.



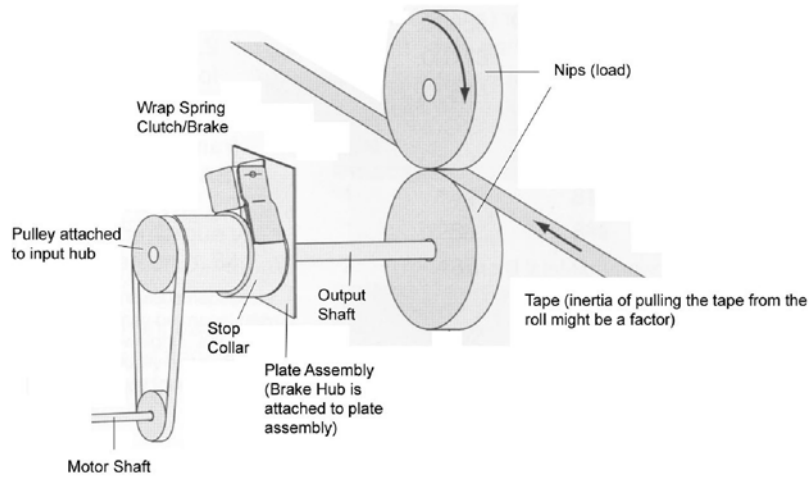


**Graphic #3** – Combination Clutch/Brake

A clutch/brake device combines the elements and functions of a clutch and a brake. It consists of an input hub, clutch spring, brake spring, stationary brake hub, and other components such as housing, and clutch and stop collars. The output shaft should have the correct diameter for spring to operate properly. Note: In the graphic above, Super features are indicated in bold.

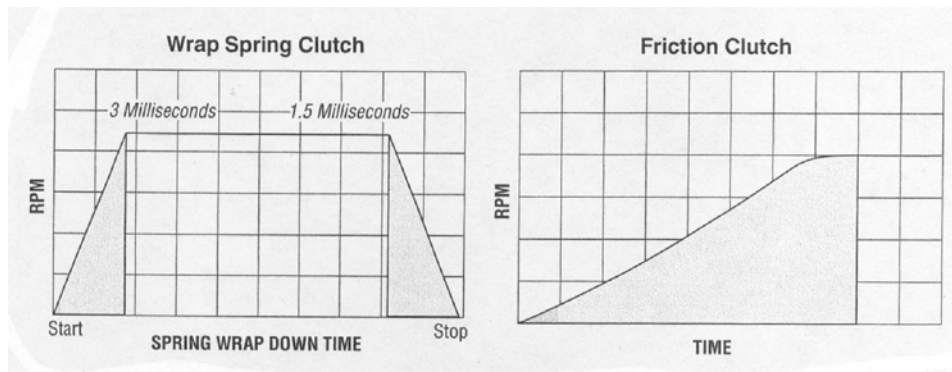


**Graphic #4** – Cut away view of Clutch/Brake



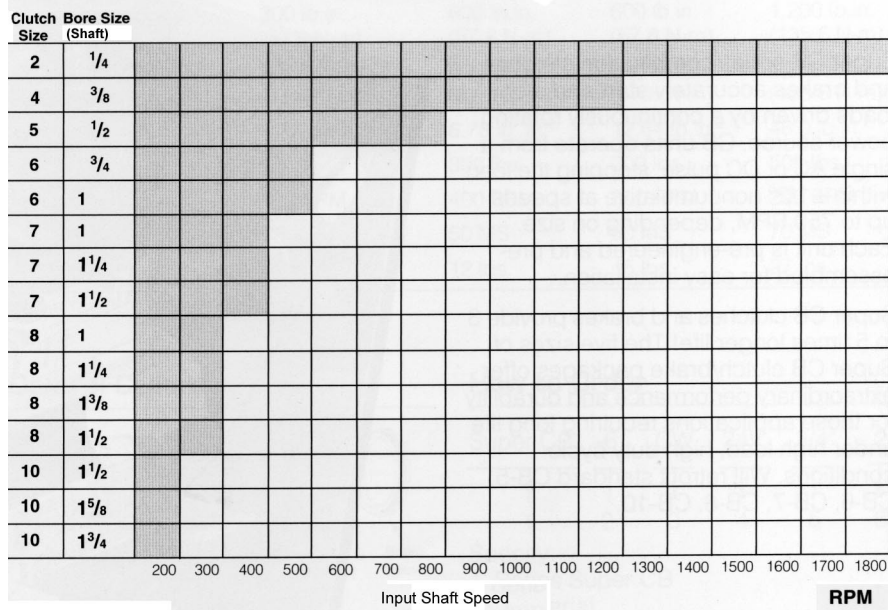
**Graphic #5 – Tape NIP Drive**

Here is an example of a tape nip driven by a motor and a wrap-spring clutch/brake. The motor rotates the input hub of the clutch/brake through a set of pulleys and a belt. The clutch/brake plate is mounted on the machine frame. The tape is pulled in accurately measured increments determined by the number and locations of the stops on the stop collar.



**Graphic #6 – Wrap Spring Clutch vs. Frictional Clutch: Starting Time Comparison**

The starting time of a positive engagement, wrap spring clutch is independent of the load inertia and friction. The starting time of the frictional clutch depends on these factors.



**Graphic #7** – RPM vs. Shaft Diameter Selection Chart

The X axis on this chart represents the shaft speed expressed in RPM, and the two columns along the Y axis are Bore Size (corresponding to shaft diameter) and the Clutch Size. The grayed area designates RPM/Size combinations within the clutch/brake design parameters. For example, at 200 RPM clutch models (sizes) are available for all listed shaft diameters. As the speed increases, the maximum shaft diameter decreases. Above 1300 RPM, only the smallest size 2 clutch/brake in combination with the 1/4 inch shaft is available.