Tension Brakes and Clutches

Design Considerations and Selection

Brakes and clutches used for tensioning (constant slip) have one thing in common. Generally, heat dissipation capacity is the primary criteria for sizing, followed by torque capacity. Beyond this, each has unique sizing requirements that differ greatly. Information on particular Warner Electric tension brakes and clutches start on page 56.

Brakes (Unwinds or Payoffs)

Thermal Requirements

Thermal requirements for a brake equals web HP; which is

$$HP = \frac{\text{Tension (lbs.)} \times \text{Linear Speed (FPM)}}{33{,}000}$$

This energy is constant throughout the unwinding process. Although energy is a function of torque and slip speed, slip speed is at its slowest when torque required is at its greatest (full roll), and slip speed is at its fastest when torque required is at its least (core). All that is needed, then to determine thermal capacity required in an unwind brake is tension and linear speed.

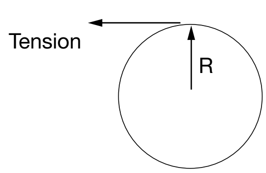
Caution should be taken, however, on machines that run more than one material at different line speeds. All combinations of tensions and line speeds should be checked to insure that brake sizing satisfies the most demanding condition (i.e. – the highest web HP).

Torque Requirements

There are generally three conditions under which a brake must supply sufficient torque: running torque, E-Stop (or emergency stop) torque and controlled stop torque (normal deceleration).

a. Running Torque

This is the torque required to maintain constant tension at any point in the roll being unwound. Since torque is force x distance, with force being tension and distance being roll radius, then torque must change as radius changes if tension is to remain constant. Moreover, the maximum running torque will be at full roll, since that has the largest radius.



b. E-Stop Torque, Web Break

This is the torque required to stop the roll in the event of a web break or a safety related machine stop. There are basically two types of stop conditions to be considered: web break where only the roll inertia stop time and RPM are major considerations, and controlled E-Stop where stopping is required due to some safety related issue, but web tension must be maintained.

During web break E-Stop controlling tension is not a major concern, but getting the roll stopped in a specified time to minimize spillage. The time frame to stop may be a company specification or an OSHA requirement.

For a web break E-Stop, the torque required is a function of roll inertia, roll RPM and E-Stop time requirements.

$$T(\text{torque}) = \frac{WR^2 \times RPM}{308 \times t}$$

where T = Torque (lb.ft.)
t = E-Stop time requirement of machine

Since the roll inertia is greatest when the roll is full, this condition is normally used for calculating the worst-case E-Stop web break torque. RPM can be determined by dividing the linear speed by the roll diameter x pi (3.1416). E-Stop times as short as 2 seconds are not uncommon.

Note that if the control system is open loop (i.e. – ultra-sonic, manual, etc.), maximum E-Stop torque must be obtained by having the S-Stop switch on the machine turn the brake to full on, otherwise the torque available will only be running torque. In the closed loop mode (dancer or load cell), maximum E-Stop torque will automatically be applied.

c. E-Stop Torque, controlled

In a controlled stop, the brake must stop the roll during the time the machine stops, all the while maintaining tension on the unwind roll. This differs from web break E-Stop torque in that the brake must stop the inertia as well as continue to maintain running torque or tension.

$$T = \frac{WR^2 \times RPM}{308 \times t} + \text{Maximum Running Torque}$$

where T = Torque (lb.ft.)
t = E-Stop time requirements of machine

It should be noted that controlled stops can only be accomplished in the closed loop mode, as feedback is required to maintain tension.

For the same stopping times, the controlled E-Stop will require more torque than the web break E-Stop, due to the additional load of maintaining tension. Controlled E-Stop torque is the worst case as the stop is the much faster than normal deceleration times.

E-Stop whether it be for controlled purposes or web break is generally a set function of the machine. Caution should be made in that the faster the E-Stop requirements, the more torque that is required of the system and the more stress that is placed on the components in the machine.

All categories must be investigated to determine the maximum torque capacity required for the application.

Other Considerations

In some instances, it may be desirable to have a gear ratio from the roll shaft to the brake, with the brake on the higher speed shaft. In addition to providing a torque multiplication equal to the gear ratio, this also serves to reduce the effective inertia that the brake sees, as reflected roll inertia is reduced by the square of the ratio. Note, however, that with brakes that have a specified drag, or minimum torque, that drag torque is also multiplied, which could result in inability to address minimum running torque at or close to core diameter.

Also, it is important to realize that employing a gear ratio **DOES NOT** reduce the heat dissipation requirement of the brake.

Another instance where a gear ratio may be needed is when any friction type brake is required to run at very low speeds, usually below 50 RPM. Although today's friction materials have been perfected to the point where static and dynamic coefficients or friction are very close, a certain amount of "sticktion" or stick slip phenomena may occur to the extent that precise control of tension may be compromised. Employing a speed-up gear ratio can make the brake operate at a more efficient speed.

Clutches (Rewinds or Winders)

Although motor drives are the more common choice for winders, clutches can be used quite successfully, and offer a more economical alternative. Typically, the input to the clutch will be a fixed RPM, and can be a take-off from the main machine drive, or an independent motor. RPM input should normally be a least 10% higher than the fastest output. To calculate this, determine the core RPM at fastest line speed, and increase this by at least 10%.

The output of the clutch will start at core RPM, and will gradually decrease as the diameter builds. As in the unwind brake, torque will vary in proportion to the diameter change, but unlike the brake, torque must increase as the diameter builds and the slip speed INCREASES. Slip speed increases because the fixed input RPM doesn't change, but the output RPM keeps decreasing as the roll diameter builds.

Energy dissipation capacity is the most critical sizing criteria in a winder clutch. Creation of heat is highest at full roll, since this is where slip speed AND torque are at their maximum. Maximum heat, or thermal HP, can be found by the following formulae:

$$HP = \frac{\text{Torque(lb.ft.) @ full roll} \times \text{Slip RPM @ full roll} \times 2 \times \text{Pi}}{33{,}000}$$

After the clutch size is selected based on the above thermal calculation, clutch torque capacity should be checked by calculating maximum torque required, which is maximum tension times full roll radius.

Taper Tension

With some materials, taper tension may be required. This is a means by which tension is gradually decreased as the roll diameter builds, and is employed if there is a risk of crushing cores due to build-up of internal pressure within the roll, or if telescoping (slippage to one side) of the wraps might occur. This becomes a function of the control, as the rate of torque increase must be reduced as diameter increases.

In single zone machines, where the unwind brake controls winder tension, taper tension can be handled in a similar fashion.

Control of the clutch can be either open loop (manual adjust or diameter compensation) or closed loop (dancer or load cell), depending upon the degree of precision needed.

For detailed sizing and selection for unwind, intermediate and rewind applications, see sizing selection section on pages 16 through 32.

Design Considerations and Selection

Design considerations and selection can be broken down by the type of system being selected and the function it must perform. Sizing and application for an unwind will be different than that for a rewind. Also, depending on whether it will be for a clutch, or brake or for a drive, certain system parameters will be required.

Additionally, will the system require a simple remote/analog control, or will it require the option of a closed loop dancer or load cell controller? These factors must be taken into consideration when sizing the proper system.

No matter which type of system is being considered, certain application parameters are necessary to make the calculations for selecting the proper components. The selection process is straight forward if the necessary data has been obtained.

An application data sheet should be used for each application to insure the necessary data is available when doing the calculations. In many cases, three or four data sheets may be used for a particular machine. Although this may seem excessive, parameters will often vary between unwind, intermediate, or rewind sections of the machine.

Unwind Sizing Tension Brakes

Once the selection data has been obtained, sizing and calculations can be started. An application example is included for both a brake sizing and a drive sizing, showing the comparison of the two type systems.

Application Data

Material: Paper; 30 lb. Basis weight
Tension: 36 lbs. max.
Roll weight: 1,100 lb. avg.
Web Width: 24 inches
Linear Speed: 800 ft./min.
Core diameter: 3.00 inches
Max. roll diameter: 42.00 inches
Machine Acceleration Time: 15 seconds
Machine Deceleration Time: 15 seconds
Machine E-Stop Time: 3.8 seconds

Note: Tension = Material Tension (PLI) X Web Width

Sizing for a Unwind Tension Brake System

1. **Energy Rate**

   Energy Rate = Tension x Linear Speed

   ER = 36 X 800

   ER = 28,800 ft. lbs./minute

2. **Thermal Horsepower**

   $$\text{Thermal HP} = \frac{\text{Energy Rate}}{\mathbf{33{,}000}}$$

   $$\text{HP} = \frac{28{,}800}{\mathbf{33{,}000}}$$

   HP = 0.873 HP

3. **Minimum Roll Speed**

   $$\text{Min. Roll Speed} = \frac{\text{Linear Speed X } \mathbf{3.82}}{\text{Max. Roll Diameter (in.)}}$$

   $$\text{Min. Roll Speed} = \frac{800 \text{ x } \mathbf{3.82}}{42}$$

   Min. Roll Speed = 72.76 RPM

4. **Maximum Roll Speed**

   $$\text{Max. Roll Speed} = \frac{\text{Linear Speed X } \mathbf{3.82}}{\text{Core Diameter (in.)}}$$

   $$\text{Max. Roll Speed} = \frac{800 \text{ x } \mathbf{3.82}}{3}$$

   Max. Roll Speed = 1,018.67 RPM

5. **Selection Speed**

   $$\text{Selection Speed} = \frac{\text{(Max. Roll Speed – Minimum Roll Speed)}}{\mathbf{10}} + \text{Min Roll Speed}$$

   $$\text{Selection Speed} = \frac{(1{,}018.67 - 72.76)}{\mathbf{10}} + 72.76$$

   $$\text{Selection Speed} = \frac{945.91}{\mathbf{10}} + 72.76$$

   Selection Speed = 94.591 + 72.76

   Selection Speed = 167.35 RPM (Selection Speed)

   Ref: Appropriate thermal curves on various catalog pages for possible brake selections (Selection Speed vs. Thermal)

6. **Minimum Roll Torque**

   $$\text{Minimum Roll Torque} = \text{Tension x } \frac{\text{Core Dia (in.)}}{\mathbf{24}}$$

   $$\text{Minimum Roll Torque} = 36 \text{ x } \frac{3}{\mathbf{24}}$$

   Minimum Roll Torque = 36 x 0.125

   Minimum Roll Torque = 4.5 lb. ft.

7. **Maximum Roll Torque**

   $$\text{Maximum Roll Torque} = \text{Tension x } \frac{\text{Max. Roll Dia. (in.)}}{\mathbf{24}}$$

   $$\text{Maximum Roll Torque} = 36 \text{ x } \frac{42}{\mathbf{24}}$$

   Maximum Roll Torque = 36 x 1.75

   Maximum Roll Torque = 63.00 lb. ft.

Note: Constant values in formulas are in bold.

Note: Refer to appropriate Running Torque vs. Speed Curves

8. Full Roll Inertia, WR^2

$$\text{Full Roll Inertia} = \frac{\text{Weight } \times \text{ Max. Dia. (in)}^2}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = \frac{1{,}100 \times (42)^2}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = \frac{1{,}100 \times 1{,}746}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = \frac{1{,}940{,}400}{\mathbf{1152}}$$

Full Roll Inertia = 1,684.38 lb. ft.^{2}

9. Roll Deceleration Torque (Normal Controlled Stop)

$$\text{Roll Decel Torque} = \frac{\text{Roll Inertia} \times \text{Min. Roll Speed}}{\mathbf{308} \times \text{Machine Decel Time}} + \text{Max. Running Torque}$$

$$\text{Roll Decel Torque} = \frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 15} + 63$$

$$\text{Roll Decel Torque} = \frac{122{,}555.49}{4{,}620} + 63$$

Roll Decel Torque = 26.53 + 63

Roll Decel Torque = 89.53 lb. ft.

10. Roll E-Stop Torque, Web Break

$$\text{Roll E-Stop Torque, Web Break} = \frac{\text{Roll Inertia} \times \text{Min Roll Speed}}{\mathbf{308} \times \text{Machine E-Stop Time}}$$

$$\text{Roll E-Stop Torque, Web Break} = \frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 3.8}$$

$$\text{Roll E-Stop Torque, Web Break} = \frac{122{,}555.49}{1{,}170.4}$$

Roll E-Stop Torque, Web Break = 104.71 lb. ft.

- This formula can also be used to check tension during acceleration. Using acceleration time of 15 seconds, torque =

  $$\frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 15} = 26.5 \text{ lb. ft.}$$

  Dividing this torque by the radius give tension, so

  $$\text{Tension} = \frac{26.5}{(42/\mathbf{24})} = 15.0 \text{ lbs.}$$

Since tension requirement is 36 lbs., acceleration is OK. If acceleration tension exceeds specified tension, a powered unwind should be considered or changing the time requirements.

11. Roll E-Stop Torque, Controlled

$$\text{Roll E-Stop Torque, Controlled} = \frac{\text{Roll Inertia} \times \text{Min Roll Speed}}{\mathbf{308} \times \text{Machine E-Stop Time}} + \text{Max. Running Torque}$$

$$\text{Roll E-Stop Torque, Controlled} = \frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 3.8} + 63$$

$$\text{Roll E-Stop Torque, Controlled} = \frac{122{,}555.49}{1{,}170.4} + 63$$

Roll E-Stop Torque, Controlled = 104.71 +63

Roll E-Stop Torque, Controlled = 167.71 lb. ft.

Refer: Appropriate torque vs. speed curves for selection of possible brakes.

Final brake sizing is determined by thermal vs. selection speed and torque vs. speed for both running and E-Stop conditions. These specifications are found in the brake selection sections starting on page 56.

A cross check of minimum running torque to minimum torque of the unit selected must also be made. If the brake minimum torque value is above the minimum running torque value, then either gearing between the unwind roll and the brake will be required, or a larger core diameter or higher tension value must be used.

Note: Not all types of tension brakes in this catalog may be suited for a particular application. Selecting a brake that is not capable of handling the system requirements will result in premature wear out or failure.

If in doubt about sizing and selection, contact your local Warner Electric Distributor, Warner Sales Representative, or the factory.

Note: Constant values in formulas are in bold.

Tension Control Systems

Design Considerations and Selection

Sizing for an Unwind Tension Drive System

Sizing for an unwind tension drive system is similar to a brake system; however, a few additional calculations are required to insure that the proper motor is selected. As before, the same system data is used to make the calculations and selection.

1. Energy Rate

$$\text{Energy Rate} = \text{Tension} \times \text{Linear Speed} \times \left\{\frac{\text{Max. Dia.(in.)}}{\text{Min. Dia (in.)}}\right\}$$

$$\text{Energy Rate} = 36 \times 800 \times \frac{42}{3}$$

Energy Rate = 36 x 800 x 14

Energy Rate = 403, 200 ft. lbs./minute

2. Thermal Horsepower

$$\text{Thermal Horsepower} = \frac{\text{Energy Rate}}{\mathbf{33{,}000}}$$

$$\text{Thermal Horsepower} = \frac{403{,}200.00}{\mathbf{33{,}000}}$$

Thermal Horsepower = 12.22 HP

3. Minimum Roll Speed

$$\text{Min. Roll Speed} = \frac{\text{Linear Speed X } \mathbf{3.82}}{\text{Max. Roll Diameter (in.)}}$$

$$\text{Min. Roll Speed} = \frac{800 \times \mathbf{3.82}}{42}$$

Min. Roll Speed = 72.76 RPM

4. Maximum Roll Speed

$$\text{Max. Roll Speed} = \frac{\text{Linear Speed X } \mathbf{3.82}}{\text{Core Diameter (in.)}}$$

$$\text{Max. Roll Speed} = \frac{800 \times \mathbf{3.82}}{3}$$

Max. Roll Speed = 1,018.67 RPM

5. Minimum Roll Torque

$$\text{Minimum Roll Torque} = \text{Tension} \times \frac{\text{Core Dia (in.)}}{\mathbf{24}}$$

$$\text{Minimum Roll Torque} = 36 \times \frac{3}{\mathbf{24}}$$

Minimum Roll Torque = 36 x 0.125

Minimum Roll Torque = 4.5 lb. ft.

6. Maximum Roll Torque

$$\text{Maximum Roll Torque} = \text{Tension} \times \frac{\text{Max. Roll Dia. (in.)}}{\mathbf{24}}$$

$$\text{Maximum Roll Torque} = 36 \times \frac{42}{\mathbf{24}}$$

Maximum Roll Torque = 36 x 1.75

Maximum Roll Torque = 63.00 lb. ft.

7. Full Roll Inertia, WR^2

$$\text{Full Roll Inertia} = \frac{\text{Weight} \times \text{Max. Dia. (in)}^2}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = \frac{1{,}100 \times (42)^2}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = \frac{1{,}100 \times 1{,}746}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = \frac{1{,}940{,}400}{\mathbf{1152}}$$

Full Roll Inertia = 1,684.38 lb. ft.^{2}

8. Acceleration Torque to Start Full Roll

$$\text{Acceleration Torque} = \frac{\text{Inertia} \times \text{Min Roll Speed}}{\mathbf{308} \times \text{Machine Accel Time}} + \text{Max. Roll Torque}$$

$$\text{Acceleration Torque} = \frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 15} + 63$$

$$\text{Acceleration Torque} = \frac{122{,}555.49}{4{,}620.0} + 63$$

Acceleration Torque = 26.53 + 63.00

Acceleration Torque = 89.53 lb.ft.

9. Roll Deceleration Torque (Normal Controlled Stop)

$$\text{Roll Decel Torque} = \frac{\text{Roll Inertia} \times \text{Min. Roll Speed}}{\mathbf{308} \times \text{Machine Decel Time}} + \text{Max. Roll Torque}$$

$$\text{Roll Decel Torque} = \frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 15} + 63$$

$$\text{Roll Decel Torque} = \frac{122{,}555.49}{4{,}620} + 63$$

Roll Decel Torque = 26.53 + 63

Roll Decel Torque = 89.53 lb. ft.

10. Roll E-Stop Torque, Web Break

$$\text{Roll E-Stop Torque, Web Break} = \frac{\text{Roll Inertia} \times \text{Min Roll Speed}}{\mathbf{308} \times \text{Machine E-Stop Time}}$$

$$\text{Roll E-Stop Torque, Web Break} = \frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 3.8}$$

Note: Constant values in formulas are in bold.

$$\text{Roll E-Stop Torque, Web Break} = \frac{122{,}555.49}{1{,}170.4}$$

$$\text{Roll E-Stop Torque, Web Break} = 104.71 \text{ lb. ft.}$$

11. Roll E-Stop Torque, Controlled

$$\text{Roll E-Stop Torque, Controlled} = \frac{\text{Roll Inertia x Min Roll Speed}}{\mathbf{308} \text{ x Machine E-Stop Time}} + \text{Max. Running Torque}$$

$$\text{Roll E-Stop Torque, Controlled} = \frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 3.8} + 63$$

$$\text{Roll E-Stop Torque, Controlled} = \frac{122{,}555.49}{1{,}170.4} + 63$$

$$\text{Roll E-Stop Torque, Controlled} = 104.71 + 63$$

Roll E-Stop Torque, Controlled = 167.71 lb. ft.

Not only does horsepower have to be calculated on thermal capacity, but horsepower must also be calculated based on both running and E-Stop torque requirements. In many cases, this will dictate a larger horsepower rating than was previously calculated for thermal capacity.

Generally, most AC and DC motors used with a drive, as is the case with most tension systems, produce 3 lb.ft. of torque over the entire speed range. The drives also provide increased current capacity for acceleration and deceleration for short time periods in the range or 150% of nominal ratings. This translates to a torque rating of 4.5 lb. ft. per horsepower.

12. Horsepower Based on Running Torque

$$\text{Running Horsepower} = \frac{\text{Maximum Running Torque}}{\mathbf{3.0}}$$

$$\text{Running Horsepower} = \frac{63.00}{\mathbf{3.00}}$$

Running Horsepower = 21 HP

13. Horsepower Based on E-Stop Torque

Normally controlled E-Stop torque will be the worst-case conditions for calculating this horsepower requirement.

$$\text{E-Stop Horsepower} = \frac{\text{E-Stop Torque, Controlled}}{\mathbf{3.0 \times 1.5}}$$

$$\text{E-Stop Horsepower} = \frac{167.71}{\mathbf{4.5}}$$

E-Stop Horsepower = 37.27 HP

As can be seen, the horsepower requirements for torque are much higher than those calculated for just thermal capacity. The motor and drive must be selected based on the largest of the three horsepower requirements.

Note: Constant values in formulas are in bold.

14. Motor HP Comparisons for Thermal and Torque

Thermal HP = 12.22 HP

Running Torque HP = 21.00 HP

Accel/Decel Torque HP = 19.89 HP

E-Stop Torque HP = 37.27

Based on the largest of the three requirements, in this case the E-Stop requirements of 37.27 HP; a 40 HP motor and drive system is required.

Note: Often a service factor will be added that will further increase the motor and drive size. This will generally depend on the severity of the application, environment, etc.

Service factors of 1.25 to 2.5 are typical for most applications.

Sizing and selection for different types of unwind systems, whether they be electric or pneumatic brakes, AC or DC drive systems, is basically the same. Though some differences may exist in the sizing and selection processes, most of the differences are revealed in the actual calculations, which are based on the type of system being considered. Acceleration, deceleration, and E-Stop requirements must be calculated for dancer and load cell type systems.

With analog or manual type systems, sizing process differences are not a factor, as the signal providing the control is a function of roll diameter only, and true machine function feedback is provided.

If deceleration and E-Stop capabilities are necessary to maintain accurate tension, then either a dancer or load cell type system must be considered. These are the only type systems that employ the full closed loop feedback needed for deceleration and E-Stop.

Control systems can be selected from the appropriate tables, page 38.

Note: In some cases a reducer or gearbox may be required between the motor or brake and the unwind roll spindle.

When sizing a reducer or gearbox, the speed is increased by the ratio and the torque is reduced by the ratio. Additionally, the efficiency of the reduction must be taken into account as this will slightly increase the required torque.

Design Considerations and Selection

Intermediate Sizing

Intermediate sizing and selection typically involves a roll that retards or pulls the web to create tension.

A brake usually provides the retarding force, while a clutch driven by a constant speed motor or a variable AC or DC drive system provides pull force.

A few additional parameters are considered in addition to those used in sizing and selecting an unwind.

Application Data

Material: Paper; 30 lb. Basis weight
Tension: 36 lbs. max.
Roll weight: 1,100 lb. avg.
Web Width: 24 inches
Linear Speed: 800 ft./min.
Core diameter: 3.00 inches
Max. roll diameter: 42.00 inches
Machine Acceleration Time: 15 seconds
Machine Deceleration Time: 15 seconds
Machine E-Stop Time: 3.8 seconds
Location of Controlling Element: Nip Rolls, S-Wrap
Roller Diameter: 6.00 inches
Roller Width: 30.00 inches
Roller Weight: 100 lbs.
Nip Roll Pressure: 25 lbs.

Sizing an Intermediate Tension Brake System

1. Nip Roll Speed

$$\text{Nip Roll Speed} = \frac{\text{Linear Speed} \times \mathbf{3.82}}{\text{Nip Roll Diameter}}$$

$$\text{Nip Roll Speed} = \frac{800 \text{ X } \mathbf{3.82}}{6.00}$$

Nip Roll Speed = 509.33 RPM

2. Tension Torque

$$\text{Tension Torque} = \text{Tension} \times \frac{\text{Nip Roll Diameter}}{\mathbf{24}}$$

$$\text{Tension Torque} = 36 \times \frac{6.00}{\mathbf{24}}$$

Tension Torque = 36 x 0.25

Tension Torque = 9.00 lb. ft.

3. Torque Due to Nip Roll Pressure

$$\text{Nip Roll Torque} = \text{Nip Roll Force} \times \frac{\text{Nip Roll Diameter}}{\mathbf{24}}$$

$$\text{Nip Roll Torque} = 25 \times \frac{6.00}{\mathbf{24}}$$

Nip Roll Torque = 25 x 0.25

Nip Roll Torque = 6.25 lb. ft.

Note: Constant values in formulas are in bold.

4. Torque Required for Tensioning

Total Torque = Tension Torque – Nip Roll Torque

Total Torque = 9.00 – 6.25

Total Torque = 2.75 lb. ft.

5. Energy Rate Required from Brake

Energy Rate = 2 x Pi X Nip Roll Speed x Nip Roll Torque

Energy Rate = 2 x 3.1415927 x 509.33 x 2.75

Energy Rate = 8,800.59 ft. lbs./minute

6. Thermal Horsepower

$$\text{Thermal Horsepower} = \frac{\text{Energy Rate}}{\mathbf{33{,}000}}$$

$$\text{Thermal Horsepower} = \frac{8{,}800.59}{\mathbf{33{,}000}}$$

Thermal Horsepower = 0.267 HP

Initial brake sizing is based on thermal requirements and operating speeds from the appropriate speed vs. thermal curves for the brake type being considered. This information is found in the brake selection section starting on page 56.

7. Normal Deceleration Torque

$$\text{Deceleration Torque} = \frac{\text{Nip Roll Inertia} \times \text{Nip Roll Speed}}{\mathbf{308} \times \text{Machine Deceleration Time}} + \text{Total Running Torque}$$

$$WR^2 = \frac{\text{Nip Roll Diameter}^2 \times \text{Nip Roll Weight}}{\mathbf{1152}}$$

$$WR^2 = \frac{6^2 \times 100}{\mathbf{1152}}$$

$WR^2 = 3.125 \text{ lb.ft.}^2$

$$\text{Deceleration Torque} = \frac{3.125 \times 509.33}{\mathbf{308} \times 15} + 2.75$$

$$\text{Deceleration Torque} = \frac{1591.66}{4620} + 2.75$$

Deceleration Torque = 0.345 + 2.75

Deceleration Torque = 3.095 lb. ft.

8. E-Stop Torque

$$\text{E-Stop Torque} = \frac{\text{Nip Roll Inertia} \times \text{Nip Roll Speed}}{\mathbf{308} \times \text{Machine E-Stop Time}} + \text{Total Running Torque}$$

$$\text{E-Stop Torque} = \frac{3.125 \times 509.33}{\mathbf{308} \times 3.8} + 2.75$$

$$\text{E-Stop Torque} = \frac{1591.66}{1170.4} + 2.75$$

E-Stop Torque = 1.36 + 2.75

E-Stop Torque = 4.11 lb. ft.

Final brake selection is based on running torque and E-Stop torque, based on torque vs. speed curves. The brake must have sufficient torque capability to handle the application. The appropriate curves for the brake type being considered should be consulted.

Note: Not all brake types will be suitable for a given application.

Sizing an Intermediate Tension Clutch System

Clutch sizing for an intermediate tension system is similar to brake sizing except the clutch input speed is recommended to be 50 to 100 RPM higher than the maximum output speed to assure proper controllability.

Using the same parameters as that for the brake sizing, sizing a clutch is as follows:

1. Nip Roll Speed

$$\text{Nip Roll Speed} = \frac{\text{Linear Speed x } \mathbf{3.82}}{\text{Nip Roll Diameter}}$$

$$\text{Nip Roll Speed} = \frac{800 \text{ X } \mathbf{3.82}}{6.00}$$

Nip Roll Speed = 509.33 RPM

2. Tension Torque

$$\text{Tension Torque} = \text{Tension x } \frac{\text{Nip Roll Diameter}}{\mathbf{24}}$$

$$\text{Tension Torque} = 36 \text{ x } \frac{6.00}{\mathbf{24}}$$

Tension Torque = 36 x 0.25

Tension Torque = 9.00 lb. ft.

3. Torque Due to Nip Roll Pressure

$$\text{Nip Roll Torque} = \text{Nip Roll Force x } \frac{\text{Nip Roll Diameter}}{\mathbf{24}}$$

$$\text{Nip Roll Torque} = 25 \text{ x } \frac{6.00}{\mathbf{24}}$$

Nip Roll Torque = 25 x 0.25

Nip Roll Torque = 6.25 lb. ft.

4. Total Torque Required for Tensioning

Total Torque = Tension Torque + Nip Roll Torque

Total Torque = 9.00 + 6.25

Total Torque = 15.25 lb. ft.

Note: Constant values in formulas are in bold.

5 Clutch Input Speed

$$\text{Clutch Input Speed} = \frac{\text{k x Linear Speed}}{\text{Nip Roll Diameter}}$$

k = 4.2 for 50 RPM Slip Difference

k = 4.57 for 100 RPM Slip Difference

$$\text{Clutch Input Speed} = \frac{4.57 \text{ x } 800}{6}$$

$$\text{Clutch Input Speed} = \frac{3656}{6}$$

Clutch Input Speed = 609.33 RPM

6. Energy Rate

Energy Rate = 2 x(Pi) π x Total Torque x Slip Speed Difference

Energy Rate = 2 x 3.1415927 x 15.25 x 100

Energy Rate = 9,581.86 ft. lbs./minute

7. Thermal Horsepower

$$\text{Thermal Horsepower} = \frac{\text{Energy Rate}}{\mathbf{33{,}000}}$$

$$\text{Thermal Horsepower} = \frac{9{,}581.86}{\mathbf{33{,}000}}$$

Thermal Horsepower = 0.3 HP

8. Acceleration Torque

$$\text{Acceleration Torque} = \frac{\text{Nip Roll Inertia x Nip Roll Speed}}{\mathbf{308} \text{ x Machine Acceleration Time}} + \text{Total Running Torque}$$

$$\text{Acceleration Torque} = \frac{3.125 \text{ x } 509.33}{\mathbf{308} \text{ x } 15} + 15.25$$

$$\text{Acceleration Torque} = \frac{1591.66}{4620} + 15.25$$

Acceleration Torque = 0.345 + 15.25

Acceleration Torque = 15.595 lb. ft.

Final clutch sizing is based on running torque and acceleration torque requirements that are based on slip RPM between input and output. The appropriate torque vs. speed curves should be consulted to insure that the clutch being considered has the necessary torque capacity for the application. See clutch information starting on page 60.

Not every model of clutch will be suitable for a given application.

Design Considerations and Selection

Sizing an Intermediate Tension Drive System

Sizing a tension drive system for an intermediate tension zone is as easy as sizing a clutch or brake. Often a reducer or gear head will be used between the motor and nip rolls being controlled.

Using the same application parameters as that for the previous brake and clutch, sizing a drive is as follows:

1. Nip Roll Speed

$$\text{Nip Roll Speed} = \frac{\text{Linear Speed} \times \mathbf{3.82}}{\text{Nip Roll Diameter}}$$

$$\text{Nip Roll Speed} = \frac{800 \text{ X } \mathbf{3.82}}{6.00}$$

Nip Roll Speed = 509.33 RPM

2. Tension Torque

$$\text{Tension Torque} = \text{Tension} \times \frac{\text{Nip Roll Diameter}}{\mathbf{24}}$$

$$\text{Tension Torque} = 36 \times \frac{6.00}{\mathbf{24}}$$

Tension Torque = 36 x 0.25

Tension Torque = 9.00 lb. ft.

3. Torque Due to Nip Roll Pressure

$$\text{Nip Roll Torque} = \text{Nip Roll Force} \times \frac{\text{Nip Roll Diameter}}{\mathbf{24}}$$

$$\text{Nip Roll Torque} = 25 \times \frac{6.00}{\mathbf{24}}$$

Nip Roll Torque = 25 x 0.25

Nip Roll Torque = 6.25 lb. ft.

4. Total Torque Required for Tensioning

Total Torque = Tension Torque + Nip Roll Torque

Total Torque = 9.00 + 6.25

Total Torque = 15.25 lb. ft.

5. Energy Rate

Energy Rate = 2 x (Pi) π x Total Torque x Nip Roll RPM

Energy Rate = 2 x 3.1415927 x 15.25 x 509.33

Energy Rate = 48,803.3 ft. lbs./minute

6. Thermal Horsepower

$$\text{Thermal Horsepower} = \frac{\text{Energy Rate}}{\mathbf{33{,}000}}$$

$$\text{Thermal Horsepower} = \frac{48{,}803.3}{\mathbf{33{,}000}}$$

Note: Constant values in formulas are in bold.

Thermal Horsepower = 1.48 HP

Initial motor selection would be for a 1.5 HP. However, this must be checked to insure that the motor will have sufficient torque capacity to handle the application.

In this application, a ratio between the nip rolls and the motor would be advantageous as it will allow the motor to operate closer to its base speed of 1,750 RPM.

To determine the ratio for the reducer or gear head, assume the maximum motor speed is 1,750 RPM.

7. Reduction Ratio between Motor and Nip Rolls

$$\text{Reduction Ratio} = \frac{\text{Motor Base Speed}}{\text{Nip Roll Speed}}$$

$$\text{Reduction Ratio} = \frac{1750}{509.33}$$

Reduction Ratio = 3.44 : 1

Based on this maximum ratio of 3.44 to 1, a 3:1 ratio would be selected for use between the motor and nip rolls. This would be a standard ratio and would be more readily available in comparison to a 3.44:1 ration.

8. Acceleration Torque

$$\text{Acceleration Torque} = \frac{\text{Nip Roll Inertia} \times \text{Nip Roll Speed}}{\mathbf{308} \times \text{Machine Acceleration Time}}$$

$$+ \text{ Total Running Torque}$$

$$\text{Acceleration Torque} = \frac{3.125 \times 509.33}{\mathbf{308} \times 15} + 15.25$$

$$\text{Acceleration Torque} = \frac{1591.66}{4620} + 15.25$$

Acceleration Torque = 0.345 + 15.25

Acceleration Torque = 15.595 lb. ft.

9. Deceleration Torque

$$\text{Deceleration Torque} = \frac{\text{Nip Roll Inertia} \times \text{Nip Roll Speed}}{\mathbf{308} \times \text{Machine Deceleration Time}}$$

$$+ \text{ Total Running Torque}$$

$$\text{Deceleration Torque} = \frac{3.125 \times 509.33}{\mathbf{308} \times 15} + 15.25$$

$$\text{Deceleration Torque} = \frac{1591.66}{4620} + 15.25$$

Deceleration Torque = 0.345 + 15.25

Deceleration Torque = 15.595 lb. ft.

10. E-Stop Torque

$$\text{E-Stop Torque} = \frac{\text{Nip Roll Inertia x Nip Roll Speed}}{\mathbf{308}\text{ x Machine E-Stop Time}} + \text{Total Running Torque}$$

$$\text{E-Stop Torque} = \frac{3.125 \text{ x } 509.33}{\mathbf{308}\text{ x } 3.8} + 15.25$$

$$\text{E-Stop Torque} = \frac{1591.66}{1170.4} + 15.25$$

E-Stop Torque = 1.36 + 15.25

E-Stop Torque = 16.61 lb. ft.

Because a 3:1 reduction is used between the nip rolls and motor, the reflected torque the motor must produce is reduced by this ratio.

11. Running Torque reflected to Motor with ratio

$$\text{Motor Run Torque}_{(reflected)} = \frac{\frac{\text{Roll Running Torque}}{\text{Ratio}}}{\text{Efficiency of Reduction}}$$

$$\text{Motor Run Torque}_{(reflected)} = \frac{\frac{15.25}{3.00}}{0.85}$$

$\text{Motor Run Torque}_{(reflected)}$ = 5.98 lb. ft.

12. Acceleration Torque reflected to Motor with ratio

$$\text{Motor Accel Torque}_{(reflected)} = \frac{\frac{\text{Roll Acceleration Torque}}{\text{Ratio}}}{\text{Efficiency of Reduction}}$$

$$\text{Motor Accel Torque}_{(reflected)} = \frac{\frac{15.595}{3.00}}{0.85}$$

$\text{Motor Accel Torque}_{(reflected)}$ = 6.12 lb. ft.

13. Deceleration Torque reflected to Motor with ratio

$$\text{Motor Decel Torque}_{(reflected)} = \frac{\frac{\text{Roll Acceleration Torque}}{\text{Ratio}}}{\text{Efficiency of Reduction}}$$

$$\text{Motor Decel Torque}_{(reflected)} = \frac{\frac{15.595}{3.00}}{0.85}$$

$\text{Motor Decel Torque}_{(reflected)}$ = 6.12 lb. ft.

14. E-Stop Torque reflected to Motor with ratio

$$\text{Motor E-Stop Torque}_{(reflected)} = \frac{\frac{\text{Roll E-Stop Torque}}{\text{Ratio}}}{\text{Efficiency of Reduction}}$$

$$\text{Motor E-Stop Torque}_{(reflected)} = \frac{\frac{16.61}{3.00}}{0.85}$$

$\text{Motor E-Stop Torque}_{(reflected)}$ = 6.514 lb. ft.

Note: Constant values in formulas are in bold.

The final selection of the motor is based on the torque/HP capabilities. Motors will normally produce 3 lb.ft. of torque per HP over the speed range when used with either an AC or DC drive. Knowing this, horsepower requirements can be based on the various torque requirements and the motor selected accordingly. Additionally, most AC and DC drives provide a 150% overload capability for a limited time for acceleration, deceleration, and E-Stop conditions.

15. Motor HP based on Running Torque

$$\text{Motor HP} = \frac{\text{Running Torque}}{\mathbf{3.00}}$$

$$\text{Motor HP} = \frac{5.98}{\mathbf{3.00}}$$

Motor HP = 1.99 HP

16. Motor HP based on Acceleration Torque

$$\text{Motor HP} = \frac{\text{Acceleration Torque}}{\mathbf{4.50}}$$

$$\text{Motor HP} = \frac{6.12}{\mathbf{4.50}}$$

Motor HP = 1.36 HP

17. Motor HP based on Deceleration Torque

$$\text{Motor HP} = \frac{\text{Deceleration Torque}}{\mathbf{4.50}}$$

$$\text{Motor HP} = \frac{6.12}{\mathbf{4.50}}$$

Motor HP = 1.36 HP

18. Motor HP based on E-Stop Torque

$$\text{Motor HP} = \frac{\text{E-Stop Torque}}{\mathbf{4.50}}$$

$$\text{Motor HP} = \frac{6.514}{\mathbf{4.50}}$$

Motor HP = 1.45 HP

19. Motor HP Comparisons for Thermal and Torque

Thermal HP = 1.48 HP

Running Torque HP = 1.99 HP

Accel/Decel Torque HP = 1.36 HP

E-Stop Torque HP = 1.45

Design Considerations and Selection

20. Minimum Motor Horsepower Selection

Minimum Motor Horsepower Selected = 2.00 HP.

This would be the absolute minimum motor horsepower that would satisfy the requirements for this application.

Note: The 2 HP motor sized does not take into account any type of service factor for the application. Typically a service factor or 1.5 to 2.5 depending on the severity of the application, environment, hours per day operated, etc. are not unrealistic.

By adding a service factor to the final requirements, you can handle any additional friction, drag, etc. that may not be known and can be handled safely. Additionally, this will also help improve the life of the motor and system as well.

Using a service factor of 1.5 in this case, the motor HP would be 2 x 1.5 = 3.00 HP for final motor size selection. This would be much more preferred over using a 2 HP in this particular application.

Rewind Sizing

Rewind tension systems are different from unwind tension systems only in that the material is being rewound on a roll. Many of the calculations are similar. However, rewind tension systems will use either a tension clutch or tension drive.

Selection data required for sizing a tension rewind system is similar to that of an unwind system. The application data form under the rewind section can be used for obtaining the proper data.

For purposes of our application example, the parameters used on the previous unwind and intermediate sections will be used.

Application Data

Material: Paper; 30 lb. Basis weight
Tension: 36 lbs. max.
Roll weight: 1,100 lb. avg.
Web Width: 24 inches
Linear Speed: 800 ft./min.
Core diameter: 3.00 inches
Max. roll diameter: 42.00 inches
Machine Acceleration Time: 15 seconds
Machine Deceleration Time: 15 seconds
Machine E-Stop Time: 3.8 seconds
Taper Tension Requirements: None

Note: Tension = Material Tension (PLI) X Web Width

Sizing for a Rewind Tension Clutch System

1. **Energy Rate**

$$\text{Energy Rate} = \text{Tension} \times \text{Linear Speed} \times \left\{\frac{\text{Max. Dia.(in.)}}{\text{Min. Dia (in.)}}\right\}$$

$$\text{Energy Rate} = 36 \times 800 \times \frac{42}{3}$$

Energy Rate = 36 x 800 x 14

Energy Rate = 403, 200 ft. lbs./minute

2. **Thermal Horsepower**

$$\text{Thermal Horsepower} = \frac{\text{Energy Rate}}{\mathbf{33{,}000}}$$

$$\text{Thermal Horsepower} = \frac{403{,}200.00}{\mathbf{33{,}000}}$$

Thermal Horsepower = 12.22 HP

3. **Minimum Roll Speed**

$$\text{Min. Roll Speed} = \frac{\text{Linear Speed X } \mathbf{3.82}}{\text{Max. Roll Diameter (in.)}}$$

$$\text{Min. Roll Speed} = \frac{800 \times \mathbf{3.82}}{42}$$

Min. Roll Speed = 72.76 RPM

4. **Maximum Roll Speed**

$$\text{Max. Roll Speed} = \frac{\text{Linear Speed X 3.82}}{\text{Core Diameter (in.)}}$$

$$\text{Max. Roll Speed} = \frac{800 \times \mathbf{3.82}}{3}$$

Max. Roll Speed = 1,018.67 RPM

5. **Clutch Input Speed**

Clutch Input Speed = Maximum Roll Speed + Slip

Note: Slip Minimum = 50 RPM
Slip Maximum = 100 RPM

Clutch Input Speed = 1018.67 + 50

Clutch Input Speed = 1068.67 RPM

Note: Clutch input speed must be at least 50 RPM greater than the maximum roll speed to provide a slip difference for controlling the output. If a locked rotor condition is used, the slip torque cannot be controlled, especially at core diameter.

6. **Slip Speed at Core**

Slip Speed at Core = Clutch Input Speed – Maximum Roll Speed

Slip Speed at Core = 1068.67 – 1018.67

Slip Speed at Core = 50 RPM

7. **Slip Speed at Full Roll**

Slip Speed at Full Roll = Clutch Input Speed – Minimum Roll Speed

Slip Speed at Full Roll = 1068.68 – 72.76

Slip Speed at Full Roll = 995.91 RPM

Thermal selection curves for the appropriate clutches should be checked to insure the clutch chosen can handle the thermal requirements at the worst case slip speed. See clutch information starting on page 60.

In this example, a slip speed of 995.91 RPM and a thermal capacity of 12.22 HP would be checked against the curves to insure that the clutch selected would have sufficient capacity to handle these requirements.

8. **Minimum Torque at core**

$$\text{Minimum Roll Torque} = \text{Tension} \times \frac{\text{Core Dia (in.)}}{\mathbf{24}}$$

$$\text{Minimum Roll Torque} = 36 \times \frac{3}{\mathbf{24}}$$

Minimum Roll Torque = 36 x 0.125

Minimum Roll Torque = 4.5 lb. ft.

Note: Constant values in formulas are in bold.

9. Maximum Torque at full roll

$$\text{Maximum Roll Torque} = \text{Tension} \times \frac{\text{Max. Roll Dia. (in.)}}{\mathbf{24}}$$

$$\text{Maximum Roll Torque} = 36 \times \frac{42}{\mathbf{24}}$$

$$\text{Maximum Roll Torque} = 36 \times 1.75$$

$$\text{Maximum Roll Torque} = 63.00 \text{ lb. ft}$$

Once maximum running torque has been determined, refer the appropriate clutch torque curves to insure that the clutch has sufficient torque at the maximum slip speed. Clutch information starts on page 56.

If the clutch selected initially does not have sufficient torque at the maximum slip speed, the next larger size unit should be checked and selected.

Acceleration torque is the final step that must be considered when selecting a clutch for a rewind application. Acceleration torque for starting the roll is in addition to the running torque needed to maintain web tension.

Worst case for acceleration torque occurs when the roll is near its maximum roll diameter. If worst-case conditions can be met, there will be no problems when starting the roll at core diameter.

10. Acceleration Torque at Full Roll

$$\text{Acceleration Torque} = \frac{\text{Full Roll Inertia} \times \text{Full Roll Speed}}{308 \times \text{Machine Acceleration Time}} + \text{Maximum Run Torque}$$

$$\text{Full Roll Inertia} = \frac{\text{Full Roll Weight} \times \text{Max. Roll Dia}^2\text{(in.)}}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = \frac{1{,}100 \times 42^2}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = 1{,}684.375 \text{ lb. ft.}^2$$

$$\text{Acceleration Torque} = \frac{1{,}684.375 \times 72.76}{\mathbf{308} \times 15} + 63.00$$

$$\text{Acceleration Torque} = \frac{122{,}555.13}{4620} + 63.00$$

$$\text{Acceleration Torque} = 26.527 + 63.00$$

$$\text{Acceleration Torque} = 89.53 \text{ lb. ft.}$$

This torque is required at the maximum slip speed of the clutch to insure the roll can be accelerated while under tension.

As can be seen, the thermal requirements for a rewind clutch are much higher than those required for the same application in an unwind situation.

Generally if the roll build diameter exceeds a 3:1 range, it is more than likely that a clutch will not be sufficient for a rewind application.

If in doubt during the sizing and selection, do not hesitate to contact your Warner Electric Distributor, Warner Electric Sales Representative, or the factory directly.

Sizing for a Rewind Tension Drive System

Sizing a motor for a rewind drive application is almost identical to that of an unwind system.

In this example, tension is constant to simplify sizing. In many applications, taper tension may be required due to the material being processed.

1. Energy Rate

$$\text{Energy Rate} = \text{Tension} \times \text{Linear Speed} \times \left\{ \frac{\text{Max. Dia.(in.)}}{\text{Min. Dia.(in.)}} \right\}$$

$$\text{Energy Rate} = 36 \times 800 \times \frac{42}{3}$$

$$\text{Energy Rate} = 36 \times 800 \times 14$$

$$\text{Energy Rate} = 403,\ 200.00 \text{ ft. lbs./minute}$$

2. Thermal Horsepower

$$\text{Thermal Horsepower} = \frac{\text{Energy Rate}}{\mathbf{33{,}000}}$$

$$\text{Thermal Horsepower} = \frac{403{,}200.00}{\mathbf{33{,}000}}$$

$$\text{Thermal Horsepower} = 12.22 \text{ HP}$$

3. Minimum Roll Speed

$$\text{Min. Roll Speed} = \frac{\text{Linear Speed X } \mathbf{3.82}}{\text{Max. Roll Diameter (in.)}}$$

$$\text{Min. Roll Speed} = \frac{800 \times \mathbf{3.82}}{42}$$

$$\text{Min. Roll Speed} = 72.76 \text{ RPM}$$

4. Maximum Roll Speed

$$\text{Max. Roll Speed} = \frac{\text{Linear Speed X } \mathbf{3.82}}{\text{Core Diameter (in.)}}$$

$$\text{Max. Roll Speed} = \frac{800 \times \mathbf{3.82}}{3}$$

$$\text{Max. Roll Speed} = 1{,}018.67 \text{ RPM}$$

5. Minimum Roll Torque

$$\text{Minimum Roll Torque} = \text{Tension} \times \frac{\text{Core Dia (in.)}}{\mathbf{24}}$$

$$\text{Minimum Roll Torque} = 36 \times \frac{3}{\mathbf{24}}$$

$$\text{Minimum Roll Torque} = 36 \times 0.125$$

$$\text{Minimum Roll Torque} = 4.5 \text{ lb. ft.}$$

Note: Constant values in formulas are in bold.

6. Maximum Roll Torque

$$\text{Maximum Roll Torque} = \text{Tension} \times \frac{\text{Max. Roll Dia. (in.)}}{\mathbf{24}}$$

$$\text{Maximum Roll Torque} = 36 \times \frac{42}{\mathbf{24}}$$

Maximum Roll Torque = 36 x 1.75

Maximum Roll Torque = 63.00 lb. ft.

7. Full Roll Inertia, WR^2

$$\text{Full Roll Inertia} = \frac{\text{Weight} \times \text{Max. Dia. (in)}^2}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = \frac{1{,}100 \times (42)^2}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = \frac{1{,}100 \times 1{,}746}{\mathbf{1152}}$$

$$\text{Full Roll Inertia} = \frac{1{,}940{,}400}{\mathbf{1152}}$$

Full Roll Inertia = 1,684.38 lb. ft.^{2}

8. Acceleration Torque to Start Full Roll

$$\text{Acceleration Torque} = \frac{\text{Inertia} \times \text{Min Roll Speed}}{\mathbf{308} \times \text{Machine Accel Time}} + \text{Max. Roll Torque}$$

$$\text{Acceleration Torque} = \frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 15} + 63$$

$$\text{Acceleration Torque} = \frac{122{,}555.49}{4{,}620.0} + 63$$

Acceleration Torque = 26.53 + 63.00

Acceleration Torque = 89.53 lb.ft.

9. Roll Deceleration Torque (Normal Controlled Stop)

$$\text{Roll Decel Torque} = \frac{\text{Roll Inertia} \times \text{Min. Roll Speed}}{\mathbf{308} \times \text{Machine Decel Time}} + \text{Max. Running Torque}$$

$$\text{Roll Decel Torque} = \frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 15} + 63$$

$$\text{Roll Decel Torque} = \frac{122{,}555.49}{4{,}620} + 63$$

Roll Decel Torque = 26.53 + 63

Roll Decel Torque = 89.53 lb. ft.

Note: Constant values in formulas are in bold.

10. Roll E-Stop Torque, Controlled

$$\text{Roll E-Stop Torque, Controlled} = \frac{\text{Roll Inertia} \times \text{Min Roll Speed}}{\mathbf{308} \times \text{Machine E-Stop Time}} + \text{Max. Running Torque}$$

$$\text{Roll E-Stop Torque, Controlled} = \frac{1{,}684.38 \times 72.76}{\mathbf{308} \times 3.8} + 63$$

$$\text{Roll E-Stop Torque, Controlled} = \frac{122{,}555.49}{1{,}170.4} + 63$$

Roll E-Stop Torque, Controlled = 104.71 + 63

Roll E-Stop Torque, Controlled = 167.71 lb. ft.

11. Horsepower Based on Running Torque

$$\text{Running Horsepower} = \frac{\text{Maximum Running Torque}}{\mathbf{3.0}}$$

$$\text{Running Horsepower} = \frac{63.00}{\mathbf{3.00}}$$

Running Horsepower = 21 HP

12. Motor HP based on Acceleration Torque

$$\text{Motor HP} = \frac{\text{Acceleration Torque}}{\mathbf{4.50}}$$

$$\text{Motor HP} = \frac{89.53}{\mathbf{4.50}}$$

Motor HP = 19.89 HP

13. Motor HP based on Deceleration Torque

$$\text{Motor HP} = \frac{\text{Deceleration Torque}}{\mathbf{4.50}}$$

$$\text{Motor HP} = \frac{89.53}{\mathbf{4.50}}$$

Motor HP = 19.89 HP

14. Horsepower Based on E-Stop Torque

Normally controlled E-Stop torque will be the worst-case conditions for calculating this horsepower requirement.

$$\text{E-Stop Horsepower} = \frac{\text{E-Stop Torque, Controlled}}{\mathbf{3.0} \times 1.5}$$

$$\text{E-Stop Horsepower} = \frac{167.71}{\mathbf{4.5}}$$

E-Stop Horsepower = 37.27 HP

15. Motor HP Comparisons for Thermal and Torque

Thermal HP = 12.22 HP

Running Torque HP = 21.00 HP

Accel/Decel Torque HP = 19.89 HP

E-Stop Torque HP = 37.27

Design Considerations and Selection

Not only must the motor selected be able to handle the heat dissipation of the application, but it also must be capable of providing the necessary torque to maintain proper tension.

Typically an AC or DC motor controlled by a frequency and/or vector drive, or a regenerative DC drive produces 3 lb.ft. of torque per horsepower over the rated motor speed range.

The HP ratings based on the largest of the 4 conditions of step 15 would be the HP rating selected for the application. In this case, since a 37.27 HP motor is not a standard, the next larger size motor would be selected. This application would require a 40 HP motor and drive system.

In many applications a reduction or gear head would be used between the motor and rewind roll. Often this will reduce the HP rating of the required motor as a torque advantage is realized with the reducer or gear head. It should be noted that the maximum ratio that can be used should never exceed a 30:1 ratio or problems will result at the low-end torque range of the motor possibly.

In the example above, no service factor was taken into account and in many cases a service factor of 1.25 to 2.5 may be considered. This would take into account any unknown friction, bearing drag, etc. in the system.

In this example if a service factor of 1.25 is used, then the motor HP and drive system would be 50 HP. By going to the larger system, motor life and trouble free operation would be realized.

For additional assistance in sizing and selecting a tension rewind drive system contact your Warner Electric Authorized Distributor, Warner Electric Sales Representative, or the factory technical support.