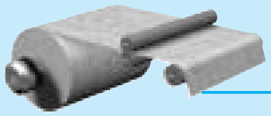


MARKET / SOLUTION

Tension control definition

*Before going through the various products and solutions **WICHITA** can offer, it is important to make a correct analysis of the need. What we call "need" is the tension control accuracy you need to operate a good material transfer through the machine and realise perfect operation on the material.*

WHAT'S TENSION CONTROL?

The tension control is the ability to permanently control the mechanical tension in any material (mainly the raw material available in roll size). This control has to be operated dynamically and statically. On every machine the operator should only be concerned with the speed and operation. The line speed is considered a master function. The tension control must be efficient at any machine speed phase, including machine acceleration, steady and speed deceleration.

Emergency stop case does not require accurate tension control but should act in the way to avoid the web breakage. It is then very important to consider all machine speed phases for the system determination.

WHY A TENSION CONTROL?

When web material has to be treated in a specific machine (printer, slitter, coater….), it is very important to transport the web with a controlled tension for two main reasons:

❒ **Correct web transport in the machine**

❒ **Correct operation on the transported material**

On the other hand, this kind of machine works very often with an "edge guiding system". Losing the tension in material will affect the correct edge guiding system.

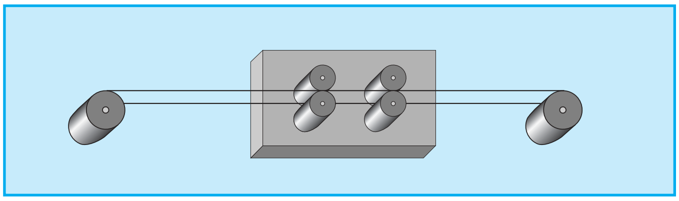
WHERE DOES IT APPLY?

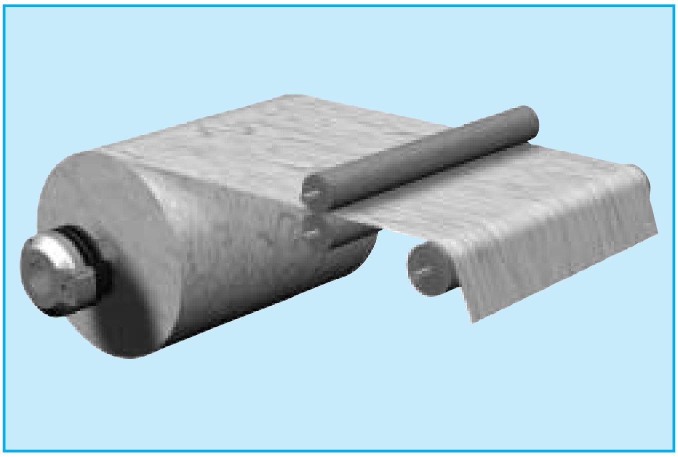
In any roll fed web processing machine. Typically:

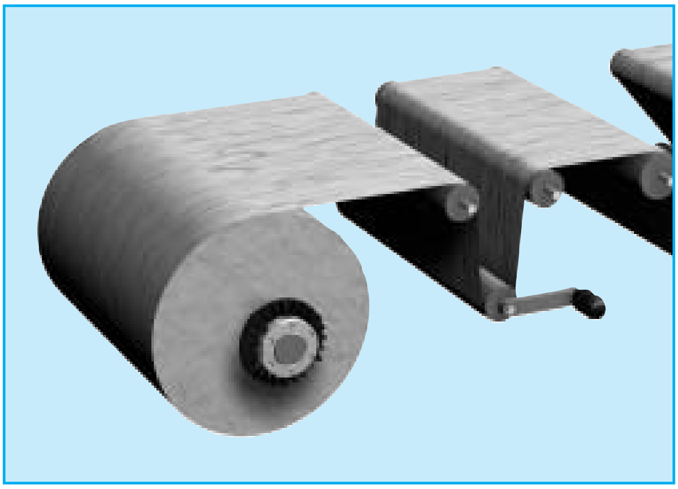
❒ **PRINTING machine**
❒ **LAMINATING machine**
❒ **SLITTING machine**
❒ **SHEETING machine**
❒ **COATING machine**
❒ **EXTRUDERS**
❒ **Stand-alone UNWINDER / REWINDER**
❒ **In general all CONVERTING equipment**

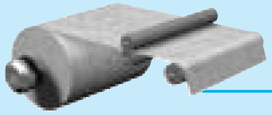
Treating material such as:
❒ **Paper**
❒ **Plastic film**
❒ **Textile**
❒ **Aluminium foil**
❒ **Wires / cables**

In general in all machines whose block diagram can be represented as follow:







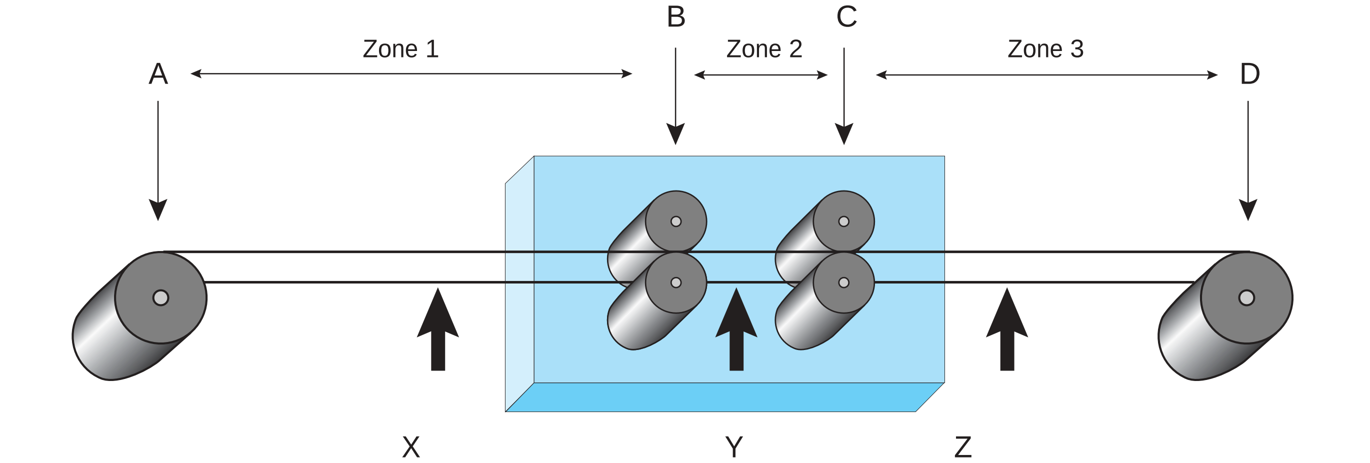


MARKET / SOLUTION

Tension control application

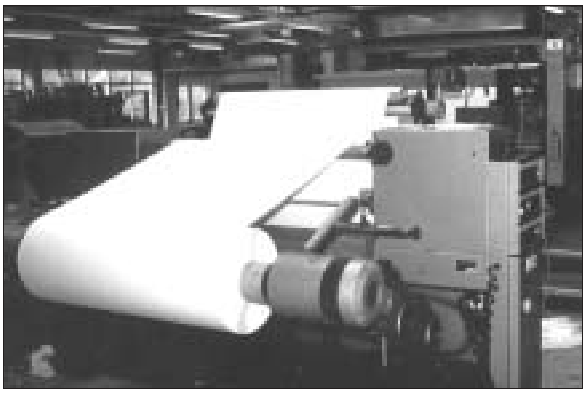
Analysing and preparing a project in tension control requires good analysis support. The general block diagram below is a good representation of any machine generally supporting tension control. We recommend you use this diagram or a part of it in any discussion and correspondence in order to be clear and to avoid possible misunderstandings.

GENERAL BLOCK DIAGRAM



IMPORTANT CONSIDERATION

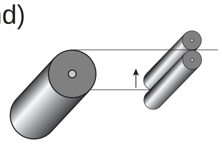
In every machine the speed point location must be clearly identified. In general one of the machine nip roll is driven setting the linear velocity of the machine. The machine speed is considered a MASTER function. The tension control, whatever the chosen solution, works in SLAVE mode. Practically, the operator sets the machine speed with a simple potentiometer and the tension control system existing on the machine has to follow, keeping the desired tension at any speed and during all transitory speed phases.



REFERRING TO THE GENERAL BLOCK DIAGRAM

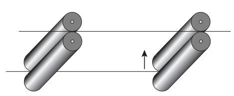
Three zones are clearly identified:

ZONE 1, Typical characteristics (unwind)



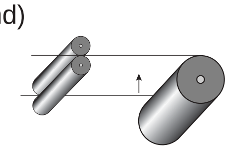
- ❒ Tension zone definition: A-B
- ❒ Speed point in B
- ❒ Variable roll rotation speed
- ❒ Variable inertia
- ❒ In general constant tension X
- ❒ Brake system applicable
- ❒ Motor system applicable

ZONE 2, Typical characteristics



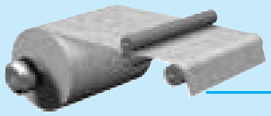
- ❒ Tension zone definition B-C
- ❒ Speed point in C or B
- ❒ Constant roll rotation speed
- ❒ Constant inertia
- ❒ In general constant tension Y
- ❒ Brake system applicable
- ❒ Motor system applicable

Zone 3, Typical characteristics (rewind)



- ❒ Tension zone definition C-D
- ❒ Speed point in C
- ❒ Variable roll rotation speed
- ❒ Variable inertia
- ❒ Constant or Taper tension Z
- ❒ Brake not applicable
- ❒ Motor system required

NOTE: Each zone is individually controlled. Tension may be different in each zone. It is assumed that there is no slipping on the nip roll.



MARKET / SOLUTION

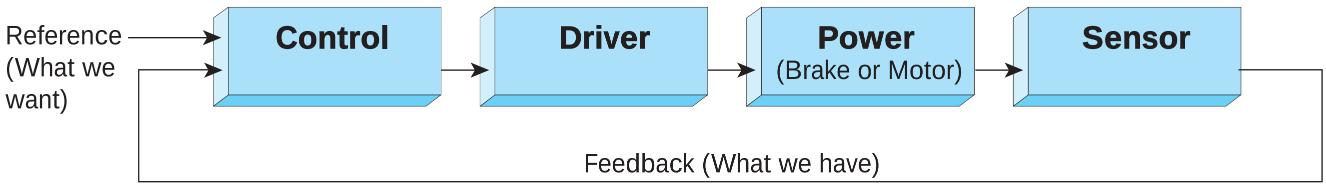
Tension control in closed loop

To create a tension it is necessary to apply a force or more precisely a torque when applied to a turning part. ***WICHITA*** *manufacture a wide range of brakes from fractionnal Nm to thousands of Nm. Two main solutions exist in terms of system configuration to apply the right torque:*

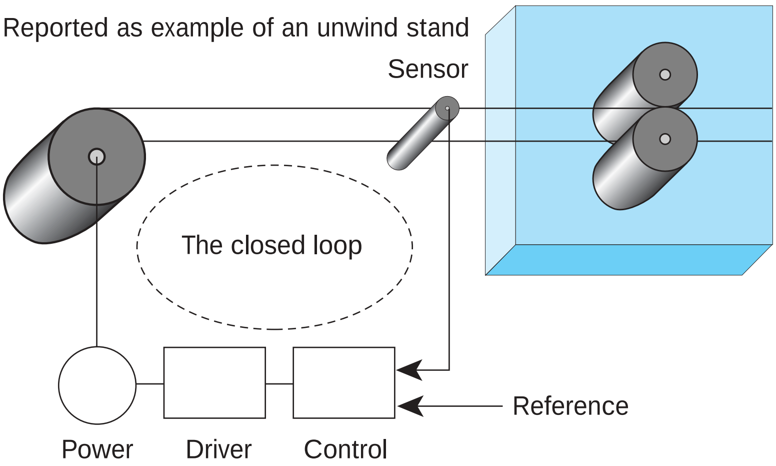
- ❒ *Closed loop control*
- ❒ *Open loop control (or more precisely open loop setting).*

CLOSED LOOP SOLUTION

The tension control, as any electronic control, is working basically in closed loop according to the electrical block diagram below. In closed loop **we sense the result we want to achieve** and compare it with a reference in order to ensure permanent balance between what we want and what we have.



Reported as example of an unwind stand



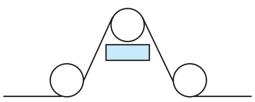
The closed loop is an electrical/mechanical loop. It is easy to understand that in such a loop all parts are important in terms of quality.

- ❒ The control – has to have high performance to manage all parameter changes correctly during the operation.
- ❒ The driver – has to be as fast as possible in terms of response.
- ❒ The power part – has to be sized correctly according to need and as fast as possible in terms of response.
- ❒ The sensor – has to be accurate, stable over time and have good repeatability.

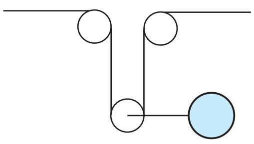
The quality of the mechanical construction is important. The control loop is closed through the mechanical transmission between the power element and the sensor roll. The web itself is a part of the loop. In the case of webs with high elasticity, special consideration should be given in control setting.

THREE WAYS TO SENSE THE TENSION

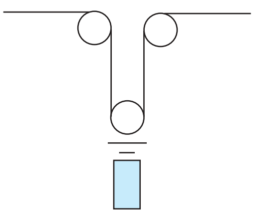
- ❒ **Direct tension** measurement with **LOAD CELL.**

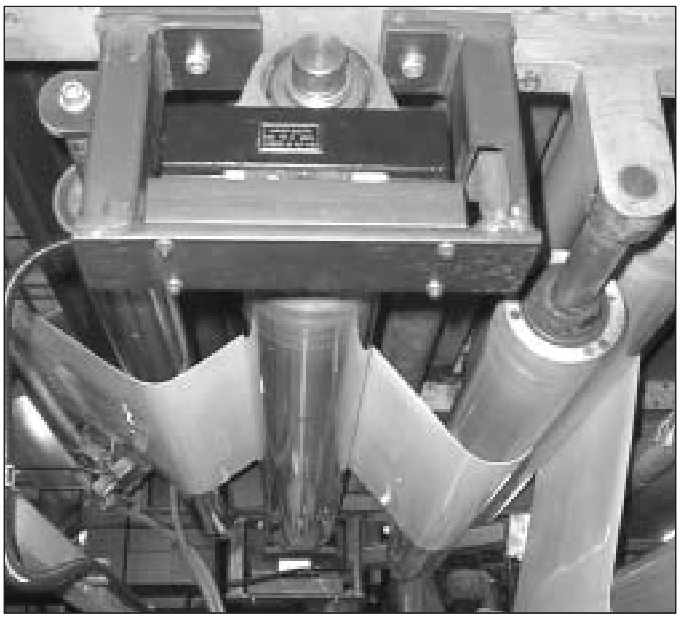


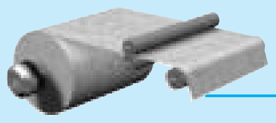
- ❒ **Indirect tension** measurement with **DANCER ARM.**



- ❒ **Indirect tension** measurement with **FREE LOOP.**







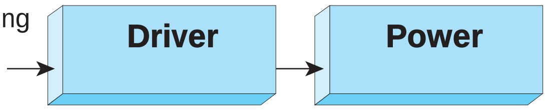
MARKET / SOLUTION

Tension control in open loop

Working in open loop requires an external reference setting applied to the driver. The torque applied to the unwind roll has to vary according to the diameter of the roll. Open loop solution is generally a low cost solution but with limited accuracy.

OPEN LOOP SOLUTION

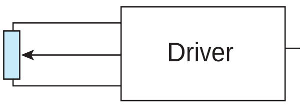
The open loop configuration does not require any control or sensor. It is composed only with a power element (brake or motor) and an associated driver. In this case the torque is **not controlled**. We have **to set the torque** on the driver according to the diameter of the roll. The electrical block schematic drawn from the closed loop system is as follows:



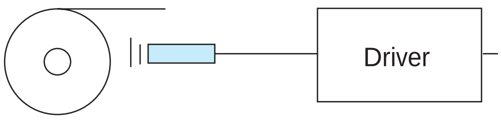
The power part is transmitting the necessary torque to the roll. Since the result is not measured, all the effect due to the inertia of the roll influence the tension in the web. Some compensations are possible but the system stays an open loop with limited accuracy.

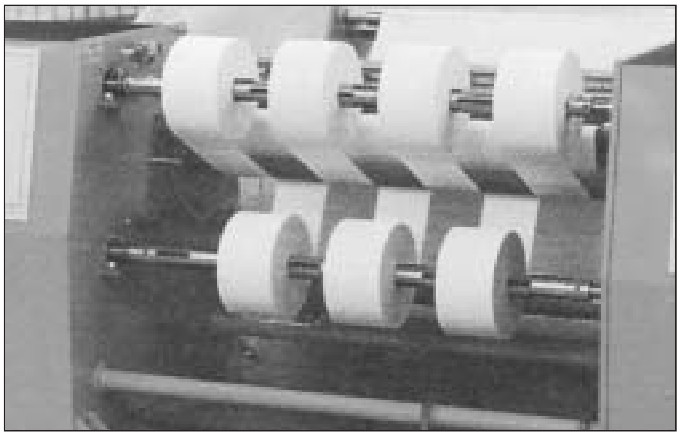
THREE POSSIBILITIES TO APPLY THE SETTING

❒ **MANUAL** by **potentiometer**

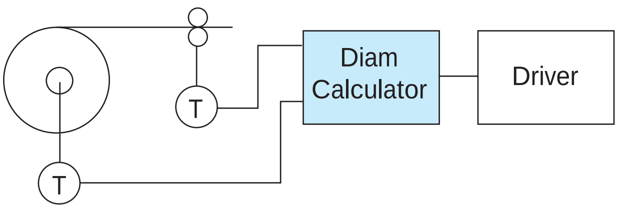


❒ **AUTOMATIC** with the **diameter reading**





❒ **AUTOMATIC** with the **diameter calculation**



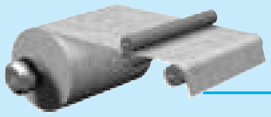
The diameter calculation is based on line and rotation speed information.

This solution requires to have both information available.

To sumarise, the web tension control can be operated in two system configurations – OPEN and CLOSED loop. For each configuration, three main possibilities for SETTING respectively SENSING are possible. The solution choice depends on:

- ❒ first, the accuracy you need in your web tension
- ❒ the mechanical construction of the machine
- ❒ the degree of automation you need
- ❒ the accelaration/deceleration imposed on the system.

In the next section WICHITA gives you some criteria to facilitate your choice. It is not our intention to impose a solution but just to offer a guide drawn from the WICHITA experience. We put the accent on the limit of various possibilities in order to start your project on a healthy base and really get the result you are expecting.



MARKET / SOLUTION

Torque and power determination

Let's take, as an example, a complete slitter-rewinder machine in order to establish a complete "power balance" sheet about the torque. The power we need in the three machine zones is the following:
- ❒ *Unwind part (zone 1)*
- ❒ *Machine process part (zone 2)*
- ❒ *Rewind part (zone 3).*

"POWER" FROM MOTOR OR BRAKE?

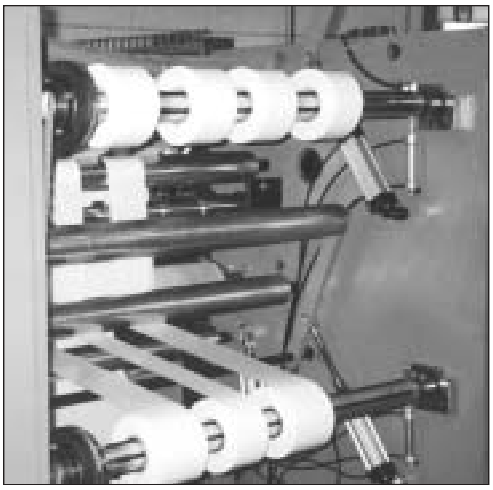
Based on two parameters:

- ❒ Do I need a positive torque or is a negative torque sufficient?
- ❒ Which technology is on the machine?

In the case where the "torque need" calculation shows positive results, we are forced to use a motor. Only a motor is able to provide positive torque. It's typically the case on the rewind stand. On the other hand, for the unwind stand the brake solution very often suits the requirements.

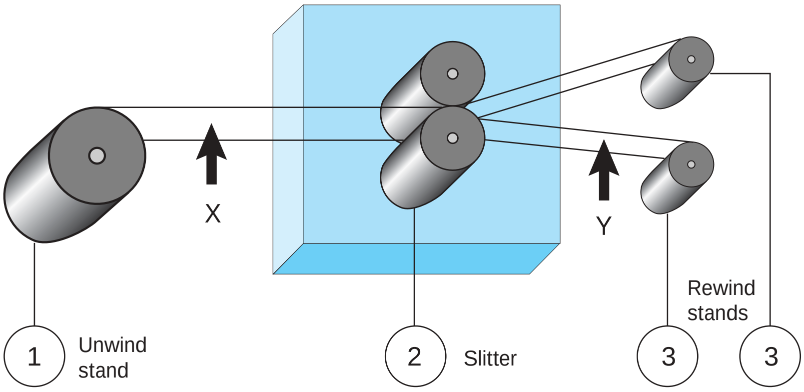
The technology parameter is purely a customer decision. The tension control with motor is today operated with AC motor and flux vector control drive with full power regeneration in the line.

WICHITA offer both solutions with a wide range of products.



TORQUE NEED EVALUATION

Example of calculation on a typical machine (slitter / rewinder).

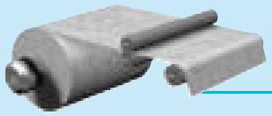


Parameters given	
Unwind tension zone X	250 N
Rewind tension zone Y	100 N, all rolls
Taper tension zone Y	40%
Max unwind roll diam.	1 m
Max rewind roll diam.	0,5 m
Min unwind roll diam.	0,09 m
Min rewind roll diam.	0,06 m
Max line speed	400 (m/min)
Accel	50 m / min / sec
Decel	150 m / min / sec
Max unwind roll weight	500 kg
Max rewind roll weight	80 kg, all rolls

Unwind stand (zone 1)

Max torque to provide the tension	–1 m * 250 N / 2	–125 Nm
Min torque to provide the tension	–0,09 m * 250 N / 2	–11,25 Nm
Inertia of the full roll	0,5 * 500 Kg * 0,5 m * 0,5 m	62,5 Kgm^2
Max rotation speed (at full line speed)	+(400 m/min / 0,09m / 3.14)	+1415 rpm
Min rotation speed (at full line speed)	+(400 m/min / 1m / 3,14)	+127 rpm
Torque to accelerate the full roll	+(62,5 Kgm^2 * 127 rpm / 9,55 / 8 sec)	+104 Nm
Torque to decelerate the full roll	–(62,5 Kgm^2 * 127 rpm / 9,55 / 2,66 sec	–312 Nm
Torque needed on the roll to insure correct tension		
– In acceleration	–125 Nm + 104 Nm	–21 Nm
– During steady speed for D to d	–125 Nm to –11,25 Nm	–125 to –11,25 Nm
– In deceleration	–125 Nm – 312 Nm	–437 Nm
– Max continuous power dissipated	–125 Nm * 127 rpm / 9550	–1,66 kW

The torque need for each machine phase shows a negative result. Brake and motor can comply with all parameters. Whatever the choice the selection must be based on the max requirements of heat, torque and speed.



MARKET / SOLUTION

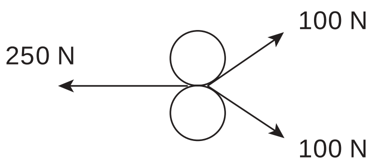
Torque and power determination

Rewind stand (zone 3)

Both shafts are similar in terms of mechanical parameters. It’s practically always the case for slitting machines.

Max torque to ensure the tension (biggest diameter, all rolls)	+(0,5 m * 100N * 60% / 2)	+15 Nm
Max torque to ensure the tension (smallest diameter, all rolls)	+(0,06 m * 100N / 2)	+3 Nm
Max shaft rotation speed – In reality the max speed is never reached on the core diameter. For the max speed on the core we can assume a practical reduction of 25%	+(400 m/min / 0,06 m / 3,14)	+2123 rpm
Then max rotation speed	+(2123 rpm * 75%)	+1592 rpm
Min shaft rotation speed – In reality the full roll is never reached at full speed For the min speed at full roll we can assume a practical reduction of 25%	+(400 m/min / 0,5 m / 3,14)	+255 rpm
Then min rotation speed	+(255 rpm * 75%)	+191 rpm
Inertia of the full roll, all rolls	0,5 * 80 kg * 0,25 m * 0,25 m	2,5 Kgm^2
Torque to accelerate the full roll, all rolls	+(2,5 kg/m^2 * 191 rpm / 9,55 / 8 sec)	+6,25 Nm
Torque to decelerate the full roll, all rolls	–(2,5 kg/m^2 * 191 rpm / 9,55 / 2,66 sec)	–18,8 Nm
Final torque need on the roll to ensure correct tension		
– In acceleration	+15 Nm + 6,25 Nm	+21,25 Nm
– In steady speed for d to D	+3 to + 15 Nm	+15 Nm
– In deceleration	+15 Nm – 18,8 Nm	–3,8 Nm
– Max power continuous dissipated per shaft	+15 Nm * 255 rpm / 9550	+0,4 kW

MAIN DRIVE NIP ROLL (zone 2)



Necessary theoretical power:

Worst tension balance = 250 N – (2 * 100 N * 60%) = 130 N

Max power need = 130 N * 400 m/min/60 = 867 W

Max roll rotation speed: depends on nip roll diameter

MACHINE POWER BALANCE

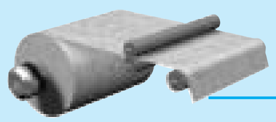
Unwind stand	–1,66 kW
Main drive	+0,87 kW
Rewind shaft (2)	+0,80 kW
TOTAL POWER	+0,01 kW
(due rounded number)	0,00 kW

Please note it is a theoretical calculation. We did not take account of all the initial friction. Looking at the torque need for each zone we can say:

- ❒ Tension function on unwind stand can be achieved by motor or brake;
- ❒ Nip roll system has to be motor driven;
- ❒ Tension function on rewind shaft must be provided by motor.

WICHITA can offer you the appropriate solution whatever your choice, wide range of electrical and pneumatic brakes as well as motorised solutions.

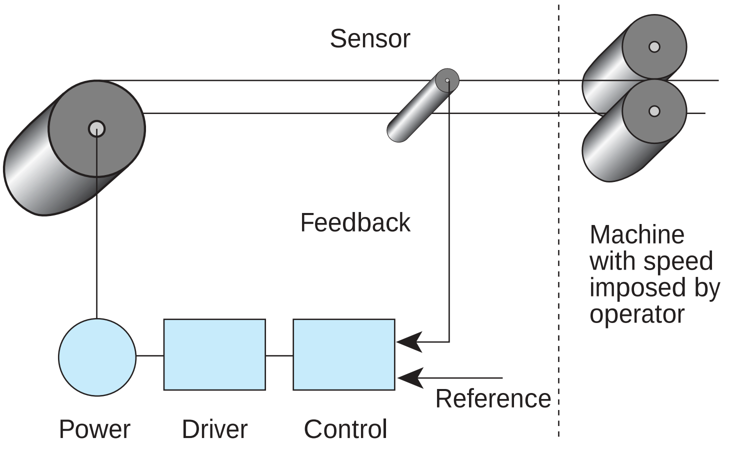
Please see pages 14 to 29 for component selection.



Configuration – selection

The power part selection is the same whatever the configuration. As soon as the power element and its associated drive are defined we have to determine how the system will be driven: in open or closed loop?
*As previously stated, one important factor is the **tension accuracy** you need.*

CLOSED LOOP – ADVANTAGES / DISADVANTAGES



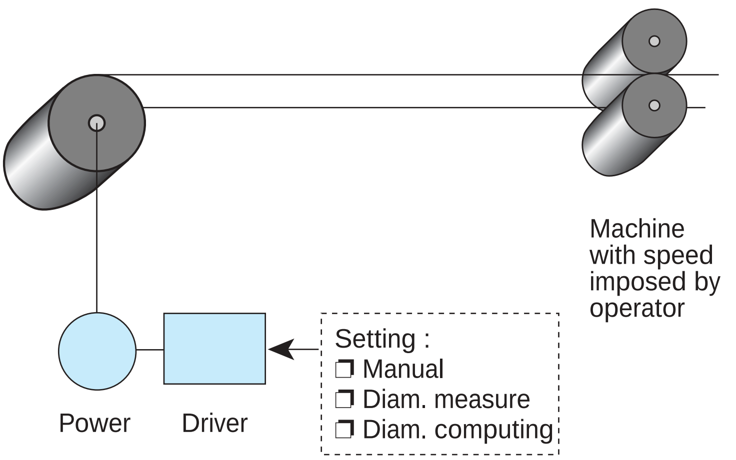
Advantages

- ❒ High accuracy
- ❒ All initial friction in mechanical parts, even if they are changing over time, are overcome
- ❒ Tension is controlled during all the machine speed phase, (accel, decel, steady speed)
- ❒ System can work in slave without any electrical connections to the machine

Disadvantages

- ❒ Risk of instability
- ❒ Can be more complex to set up
- ❒ More expensive compared to open loop

OPEN LOOP – ADVANTAGES / DISADVANTAGES



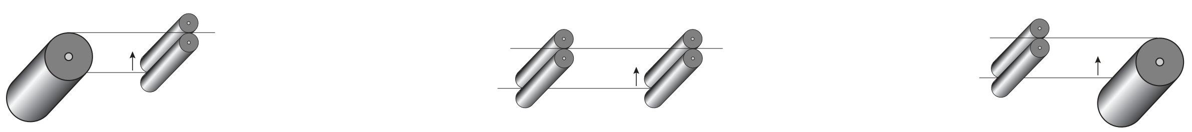
Advantages

- ❒ Very stable
- ❒ Easy to start up
- ❒ Low cost compared to closed loop (sensor and control units not required)

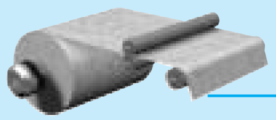
Disadvantages

- ❒ Poor accuracy
- ❒ Strongly dependent on quality of mechanical parts
- ❒ Accel, decel phase reflected on tension

DO NOT FORGET: all above considerations – even if example is unwind stand – are applicable to the three various machine zones we have defined on page 5.



Every zone of the complete machine can be controlled with its own appropriate tension system configuration. A typical example is the tension in a printing machine. It is very often controlled on an unwind stand in closed loop where the accuracy is important for good printing and on a rewind stand in open loop where the tension precision is not so important after the print operation.
Finally it's the customer's decision. WICHITA can offer advice in solution and product choice.

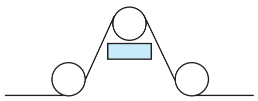
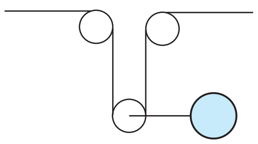
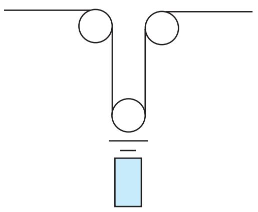


MARKET / SOLUTION

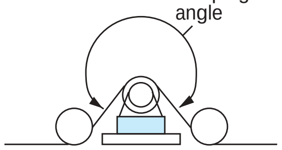
Closed loop – Sensor selection

If your machine requires a very accurate web tension control, then you need to work in closed loop. An important unit in the loop is the sensor. Three main possibilities are offered. The choice is now depending on the kind of machine you are building, the mechanical construction and the max tension value you desire to control.
***WICHITA** bring you their experience for selection according various criteria.*

MAIN APPLICATIONS – ADVANTAGES – DISADVANTAGES FOR THE THREE POSSIBILITIES

Type of sensor	Where, When, Why?	Advantages	Disadvantages
Load cell 	❒ Slitter, Sheeter, Coater ❒ For heavy material ❒ Limited room ❒ No fast accel/decel ❒ Tension peak accepted	Direct tension measure Mechanically well integrated No moving part	No tension peak absorption Accel/decel machine not easy to manage Flying splice function not easy
Dancer arm 	❒ Printing ❒ Intermittent function ❒ Flying splice need	Absorb tension peak Can act as store Easy flying splice Accel / decel machine phase well absorbed Flexibility	Need more space Moving parts
Free loop 	❒ Textile machine ❒ Very low tension	Same as dancer arm	Same as dancer arm Reliable position reading not easy

❒ In all cases the machine speed profile is important. The accel/decel machine ramps have to be electrically managed.
❒ In any mechanical construction (dancer arm), all the inertia has to be minimised.

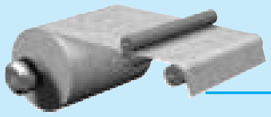


LOAD CELLS SIZING – MOUNTING RECOMMENDATIONS

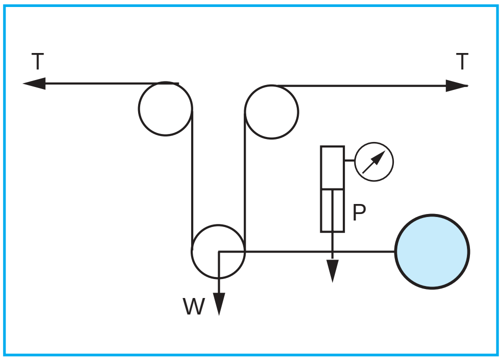
Please keep this principle in mind: The load cell installed is destined to measure the WEB TENSION and not other constraints applied to it.

Take the following points into consideration before selecting, sizing and installing material components.

❒ Load cells location should be vibration-free. Vibrations will decrease quality measurement.
❒ The sensing shaft fitted on or in has to be very well balanced. An unbalanced shaft will create measurement oscillation, causing variations in control quality.
❒ Adapted ball bearing has to be used to avoid original stress on load cell (self-aligning ball bearing).
❒ Choose a reasonable sensing shaft weight/web tension measure ratio. Less than 1.
❒ Do not oversize the load cell in your calculation. Max admitted factor 3, recommended 1,5.
❒ Choose a minimum wrapping angle on load cell. Min = 240°.
❒ So far as it is possible, use load cell in compression, with web tension effect in same direction as the weight of shaft.



Closed loop – Sensor selection



DANCER ARM BUILDING AND OPERATIONAL RECOMMENDATIONS

Dancer arm system is used for indirect tension measurement. It is in fact a position control. The desired web tension is provided with an external component. As general principle keep this concept in mind:

We have to create tension with force and not with a weight.

Take the following points into consideration before manufacturing, sizing and installing the components.

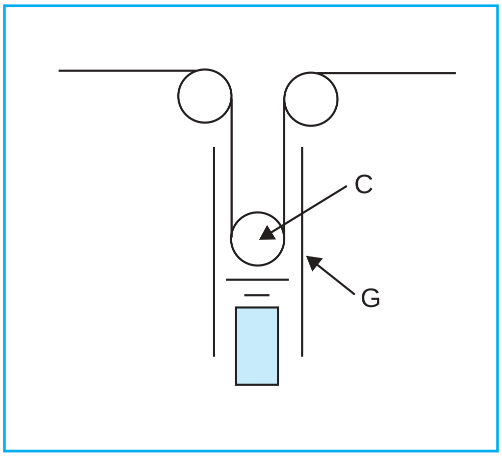
❒ Moving part of dancer has to be as light as possible.

❒ The dancer can act as both position control and web accumulator.

❒ The larger the quantity of material stored in dancer, the easier will be the position control, and hence the tension control.

❒ To set tension you need to use a pneumatic actuator “P” acting on arm of the swinging roll.

❒ In case of light tension do not add balance weights to compensate for excessively heavy dancer arms, but choose free loop.



FREE LOOP INSTALLING RECOMMENDATIONS

This is an indirect tension measure. It is in fact a position control similar to the dancer arm. The loop position is read with ultrasonic sensor. Free loop is applied especially in the textile market where tension required is generally low. The free loop system suits the requirement expressed as “zero tension”. Main difficulty is to obtain a reliable position reading.

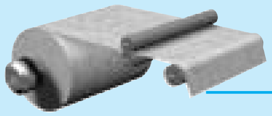
For free loop operation the following points should be taken into consideration:

❒ The tension in material is the own weight of material in the loop.

❒ A light core “C” is often placed in the loop to immobilise the loop, making the position reading easier.

❒ As the system is very light it is very sensitive to “wind”. Some guards “G” are installed to prevent accidental loop moving.

❒ As the system is dedicated to very low tension it often requires a motor power system.

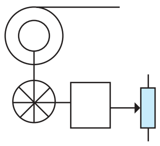
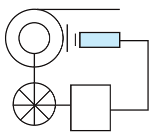
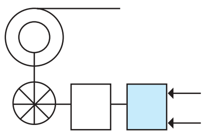


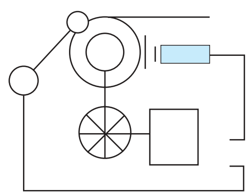
MARKET / SOLUTION

Open loop – Setting selection

Working in open loop requires that a torque setting is defined. As seen on page 7, three possibilities exist. The choice depends on the machine complexity and the automation required. One important factor that remains is the tension precision. For unwind and rewind systems the diameter ratio will play an important role. Working in open loop also requires special considerations regarding system inertia.

MAIN APPLICATIONS – ADVANTAGES / DISADVANTAGES FOR THE THREE POSSIBILITIES

Setting type	Where, When, Why?	Advantages	Disadvantages
Manual setting by pot 	❒ Cable machine ❒ No fast accel/deccel ❒ Low roll diameter ratio ❒ Operator intervention admitted	❒ Low cost solution ❒ Easy to start up	❒ Tension precision depends on operation
Diameter reading 	❒ The most commonly used solution in open loop ❒ No operator intervention admitted ❒ Large roll diam ratio	❒ Physical reading, no reset ❒ Easy to start up	❒ Poor reading accuracy on core
Diameter computing 	❒ In rewind station ❒ In sophisticated machine ❒ Large roll diam ratio	❒ Electrically integrated ❒ Easy compensation for transitory phases	❒ Need line speed signal ❒ Need roll rotation speed signal ❒ Can be complex to set up ❒ Need reset
❒ All solutions remain an open loop solution with limited precision. ❒ As we do not measure the result we want to achieve, all initial friction and inertia influence the precision of the system.			



SOME PRECAUTIONS WHEN USING READING SOLUTION

Reading solution is generally with **ultrasonic sensor**. Another type of reading is **the roll arm follower**. Both use the same principle. The roll diameter measure is applied as torque setting on the power part driver. The sonic reading offers the advantage of not touching the roll. The reading reliability is the weak point of the system. Ultrasonic sensor location is important and should respect the recommendations below.

The block diagram used in all ultrasonic open loop applications shows the sonic in any position. The position shown in explanation is not necessarily the ideal position to get good reading reliability. The problem when using sonic reading is to get signal reliability at the end of the roll when approaching the core. The best position when applicable is the position shown on this diagram where the sensor position axis is voluntarily offset from the theoritical vertical axis. Placing the sensor axis in X position will ensure a good and stable reading even at the end of the roll. The small error provided is not important and the reading stability is guaranteed.