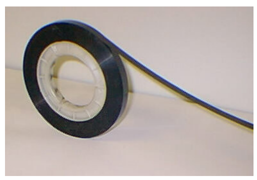
DOUBLE R CONTROLS' CONCEPT OF CONTINUOUS PROCESS WEB HANDLING PRINCIPLES



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INTRODUCTION

Over the past years the users of flexible packaging materials have been demanding thinner and stronger films to enable them to achieve greater yields. At the same time the manufacturers and converters of the materials have had to increase their process speeds in order to maintain a competitive edge. The combination of thinner webs and higher speeds has caused many web handling problems, these have been overcome by the use of more technologically based machinery as opposed to conventional equipment. Double R Controls have developed numerous programmes and equipment to change the **'black art'** of web handling to a science in order to provide good roll quality from the equipment they manufacture, whether it be spooled or conventionally wound reels. The following information is our view of the optimum winding techniques to enable thin films to be processed at high speed and provide the ultimate end user with a quality finished package.

Correct web handling techniques are of paramount importance to the converting industry since every operation when winding or unwinding a web influences the quality of the finished product. ***The requirement of any roll is to wind it at the lowest tension possible, but enable the roll to be unwound and transported without telescoping***. The roll quality ultimately controls the efficiency of the final machine which processes the roll of material and therefore has an influence on the production efficiency and customer satisfaction. For this reason Double R Controls have developed various winding principles which are optimised for the particular type of material being processed, whether this be a product of 0.2 mm wide which is spooled or a product which is a number of metres wide wound in a roll form. Facilities are available from Double R Controls to demonstrate the optimum winding principle for the product to be processed.

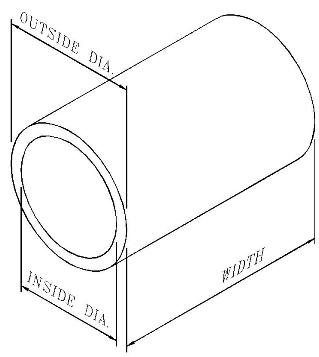
Web handling is the controlled transfer of a web from the unwind of a machine to the rewind or, simply, the unwinding of the web for the process. The principles described here are associated with continuous web movement as opposed to sheet web movement. To maintain control of the web, correct web handling techniques are essential in all phases of the operation between the unwind and the rewind.

However, the optimum web handling techniques are not easy to define and differ with the type of material and thickness of material being processed. It is therefore necessary to understand the basic terminology used, the properties of the material and the factors which cause these problems before discussing the best web handling techniques.

TERMINOLOGY AND PHYSICAL PROPERTIES OF MATERIAL

CORE

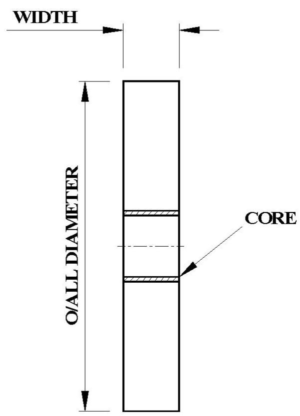
Cores are simple cylindrical tubes having no side flanges. Material, both mini jumbos and spools, are wound onto cores.



REEL DENSITY

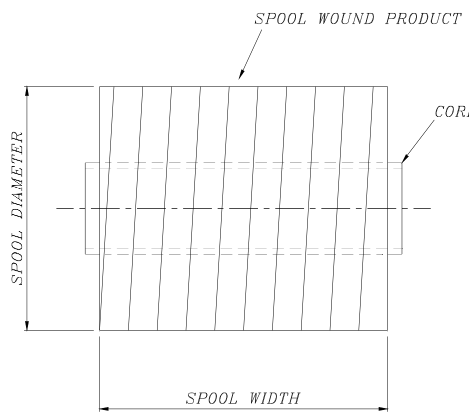
Reel density is the mass per unit volume of the finished spool. It should be noted that there are basically two roll densities. One is the unstressed material density and the other is the wound roll density. The unstressed material density is purely the weight of the material divided by the volume when it is in an unstressed condition. The wound roll density is the weight of the reel divided by the volume of material, not forgetting to exclude the weight and volume of the core section. In 1970 an article by Shvetsov compared these densities as a density index which was equal to the rewound roll density divided by the unstressed material density. Density is a measurable quantity and is useful as an indicator of roll quality. When winding a reel the density is controlled by the wound-in tension, however, when spooling a product the density can vary by the wound-in tension as well as the overlap of the material.

PANCAKE/PLANETARY WOUND



Pancakes or planetary wound products are reels that have a diameter significantly larger than their width, for example, a reel of 300 mm diameter on a 76 mm core having a width of 10 mm would be described as a pancake or planetary wound reel.

SPOOL/TRAVERSE/LEVEL WOUND



Level winding is the generic term used for spooling products. The principle is to form a spool by traversing the material across the face of the core and, at the appropriate time, reverse its direction so the material traverses in the opposite direction, thus building up a number of layers until a finished spool is created. The general characteristics of a spool wound product are essentially a very poor wound pancake. However, the industry accepts the appearance of the spool which has annular rings at the end that are created by the reversal point of the tape during the spooling process.

The edge of the spool is the most vulnerable point and it is of paramount importance that anyone handling the spool does not press the side as it will cause damage to the product.

This is a particular problem if the material is adhesive, as the layers of material that protrude at the end of the spool will then adhere together and create a problem during the de-spooling process. To optimise the efficiency of de-spooling, it is important that the equipment used is designed for de-spooling the particular product being unwound. Quite often, users of a spooled product do not use the correct technique and, therefore, do not obtain the maximum advantage of a spooled product. This is the reason why Double R Controls Ltd. work as a partner with their customers and we have a wide range of de-spooling equipment to optimise the efficiency of unwinding the material. There are many ways the quality of the spool wound product can be increased and, therefore, it is essential that the winding characteristics for a particular product are optimised to ensure both the stability and the appearance of the finished spool are the best.

Using the latest technology, once the winding characteristics have been optimised for a particular product, these can be stored electronically within a computer programme. This data can then be retrieved and applied to the winding principles for the particular product to be processed, thus reducing any second learning curve for that particular material.

To achieve the optimum rewound reel and transfer of the web from the unwind to the rewind it is important to understand the physical properties of the material. The elastic modulus, yield stress, thermal stability, thickness and the coefficient of friction of the material are the most important. Also, when processing open adhesive products an understanding of the characteristics of the adhesion is important. A knowledge of these properties will provide the user with a better understanding of the problems involved when processing the different materials.

Elastic Modulus

The elastic modulus of a material can be defined as the ratio of tension to web deformation below yield stress point for a given material. Deformation is the amount of elongation or stretch in a material for a given length and is usually expressed in cm/cm of web length.

$$\text{Elastic Modulus} = \frac{\text{Stress}}{\text{Strain}} = \frac{\text{Tension}}{\text{Deformation}}$$

Stress = Applied force/cross section area of material

Strain = Extension/original length (deformation)

Tension = kg/cm (or N/cm) web width - cm of material thickness

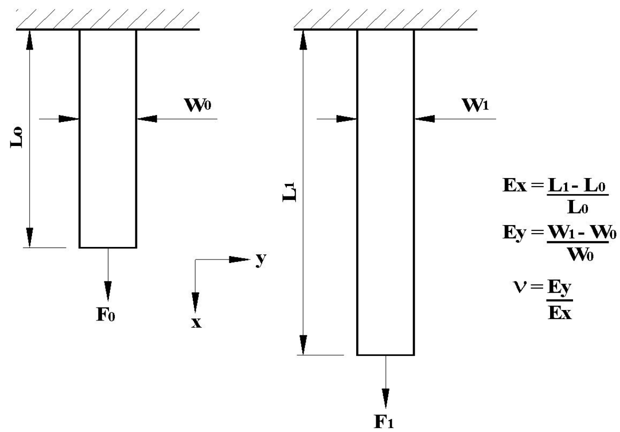
Deformation = cm/cm original length

Deformation (Extension)

Deformation of the material is the amount of elongation or stretch of the material for a given force and is expressed in centimetres per centimetre of web length.

Poisson's Ratio

'Poisson's Ratio' states that when stress is applied stress to an isotropic material in the cross direction, we induce stress in the perpendicular direction. The resulting ratios between the perpendicular stresses and strains is called Poisson's Ratio.



$$\frac{E2}{E1}$$ (cross direction of the material) / (axial or machine direction modulus)

Based on this, the width of the product varies as it goes through a converting process due to Poisson's Ratio and necking of the material will take place. It is therefore important to slit the product under the minimum tension or stress as possible to reduce this effect. The Poisson's Ratio for nonwovens and foams is extremely high, whereas for papers and steels it is relatively low. Poisson's Ratio is extremely important as it is the effect on normal product width and product width variations. Under no load the specimen has a length and width of L0 and W0 respectively. Under tensile load in the direction of *x* the length will increase to L1. The strain in the direction of *x* will be:

$$Ex = \frac{L1 - L0}{L0}$$

However, the width will also neck from W0 to W1. The strain in direction *y* (perpendicular to the load direction) is:

$$Ey = \frac{W1 - W0}{W0}$$

It can be seen that the lateral strain, by convention, will be negative. Poisson's Ratio is defined as the ratio of the strain during uni-axial loading, i.e. loading in direction of *x* only.

$$\nu = \frac{-E_y}{E_x}$$

The negative sign, by convention, makes Poisson's Ratio in almost all cases negative. It can be seen from Poisson's Ratio that if a product is extended during a process, especially prior to slitting and then relaxed, the width of the product will be greater when relaxed than during the slitting operation. This is particularly a problem when processing extensible materials such as thin gauge polyethylene, foams and nonwoven products.

TENSION

Tension is the force or pull applied to a web and is usually expressed in kilograms per centimetre or Newtons/centimetre of web width, or can sometimes be expressed in kilograms per centimetre of web width per micron of web thickness. Figure I shows a typical stress strain curve for a filmic type material.

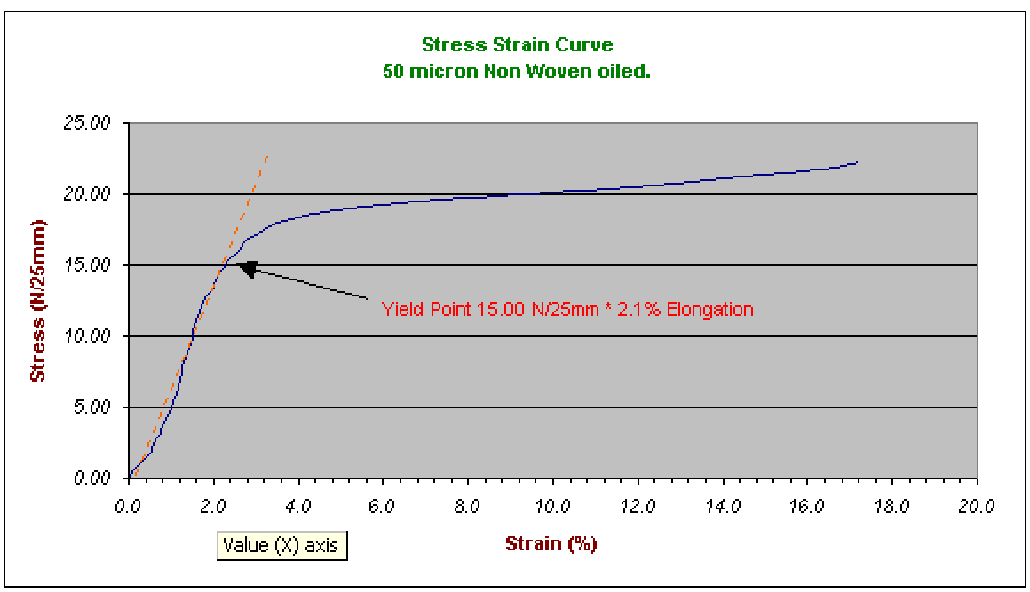
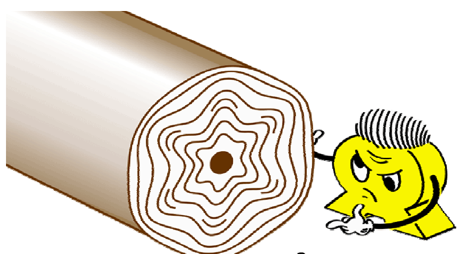


Figure I

A material with a high elastic modulus such as paper or aluminium foil elongates or stretches very little as higher tension is applied. However, a film with a low elastic modulus such as polyethylene will elongate extensively when even moderate tensions are applied. The yield stress point for a material is the point when it will not return to its original length after additional tension forces are applied. All materials will stretch or elongate during the transportation or winding process, however, the degree of elongation or percentage of stretch of a film must be kept to an absolute minimum at all times.



Most filmic materials have a memory and once they have been retained in the rewind section of the machine they will try and return to their original length which will cause excessive radial pressures within the rewound reel causing starring on the reel or crushing of the core.

Control of elongation is therefore critical for good winding. The elongation or percentage of stretch of a film at room temperature can be calculated from the total force applied and the elastic modulus of the material.

$$\text{Elongation} = \frac{\text{Tension (Newtons)} \times 10{,}000}{\underset{(\text{N/cm}^2)}{\text{Elastic Modulus}} \times \underset{(\mu\text{m})}{\text{Thickness}} \times \underset{(\text{cms})}{\text{Width}}}$$

$$\text{Percentage Stretch} = \text{Elongation} \times 100$$

Where elongation is centimetres stretched per centimetre of web length, tension is total web tension in Newtons, elastic modulus is in Newtons per centimetre squared, thickness is in microns, width is the web width in centimetres.

YIELD STRESS

The yield stress point is the point where, if the tension applied to the material is increased further, the material will not return to its original length and therefore permanent deformation begins to occur, no material should ever be wound approaching this tension level. Polyamide materials also begin to elongate very rapidly from this point with only small increases in tension. Below the yield stress point and even at low tension levels, elongation of the web occurs, however, the web will normally try and return to its original length when the film is relaxed or rewound. Depending on the degree of tension or elongation created within the material, the forces that can be generated within a wound reel can be so great that the core will crush as the material attempts to return to its original length. The yield stress point varies with each type of material, the temperature of the material and the thickness of the material.

THERMAL STABILITY

An increase in web temperature will lower the elastic modulus and the yield stress point of most films. Typically, for a plastic web the yield stress point is reduced by approximately thirty per cent when the temperature of the material has been increased from 20ºC to 45ºC. It is therefore of paramount importance to operate at low web tensions when handling low modulus films at elevated temperatures. It is also critical when processing product which is at an elevated temperature that the temperature is reduced to ambient prior to rewinding taking place.

THICKNESS

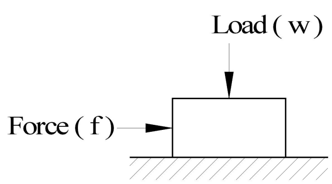
The thickness or gauge of a film is an important measurement for the material being processed because of its effect on the tension/elongation curve. Theoretically the same amount of web tension will cause twice as much elongation when the film gauge or thickness is halved. The yield stress point is also reduced as the thickness is lowered. Web stiffness is a function of the cube of the thickness of the material, i.e. if the thickness of the film is doubled then the stiffness is increased eight times. Within certain limits heavier gauges of the same material are easier to handle than thinner gauges.

Heavier gauges require less transportation support and have less tendency to distort and elongate at a given web tension and web speed. Thickness is measured in microns, gauge and mills.

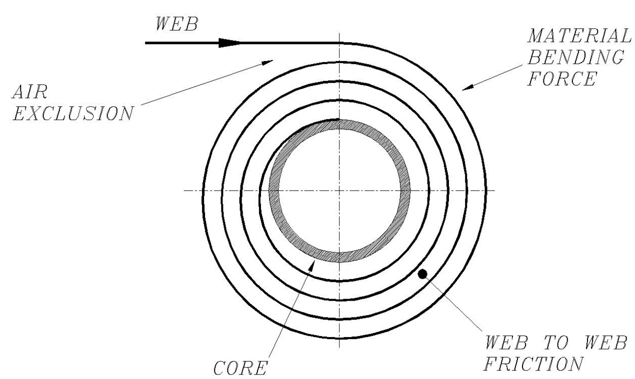
1 angstrom	=	0.000001 of a millimetre
1 micron	=	0.001 of a millimetre
1 mill	=	0.001 inch
100 gauge	=	0.010 inch

COEFFICIENT OF STATIC FRICTION

The coefficient of friction of a material is the amount of grip which takes place between two layers of the material or the layer of material and a roller that is transporting the material. It is defined as the ratio of the tangential force required to move one object on another and the perpendicular force pressing the two together. The lower the coefficient the easier it is to slide one surface over another (high slip level), such as siliconised materials.



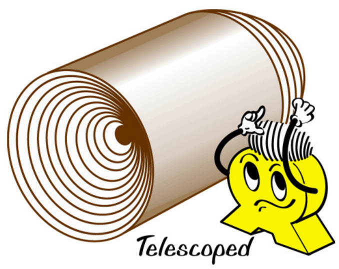
$$\mu = \frac{f}{w}$$



The grip levels of films are usually classified as high, medium and low slip. High slip films usually have a coefficient of friction (film to film) below 0.2, medium grip films are 0.2 to 0.5 and low grip films are 0.5 and above. The degree of grip level is important when transporting a web and optimising winding techniques. The degree of slip between a material and a roller is critical when using spreader rolls and therefore it is necessary to know the type of material being processed to optimise the spreading technique. Slippage can be reduced by increasing the contact area or increasing surface roughness. (Increase coefficient of friction.)

CONTROLLING WEB TENSION

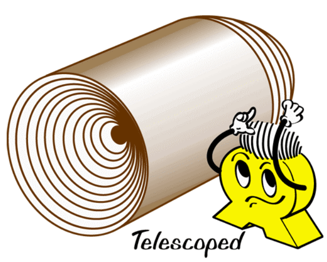
Tension is the most important single factor in any web handling process. When processing a material through a machine, a constant tension profile is critical. The absolute level of tension is not always the most important factor, but the consistency of tension is. When winding a web, varying tension profiles are necessary to optimise the winding. Tension is the force or pull applied to a web and is usually expressed in kilograms per centimetre or Newtons per centimetre of web width. Tension can also be expressed in kilograms of web width per micron of material thickness.

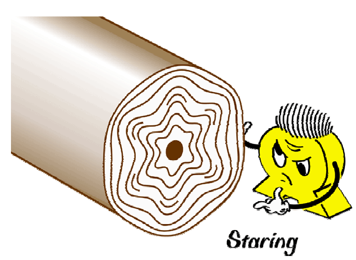


When winding a reel, often high degrees of tension have to be applied to exclude air from between the layers of material to prevent the reel telescoping or the layers sliding.

However, other techniques should be used instead of tension to reduce air entrapment between the layers as the increase in tension can cause deformation to the material or, when the reel has been wound, the material will try and return to its original length causing distortion to the finished roll. Lack of tension causes soft rolls.

High tension causes crushed cores and telescoped reels.

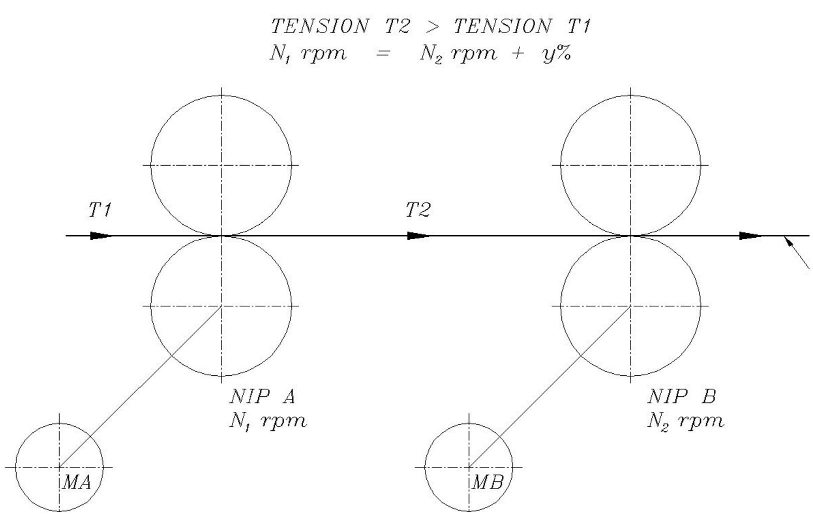




CAUSES OF TENSION CHANGES

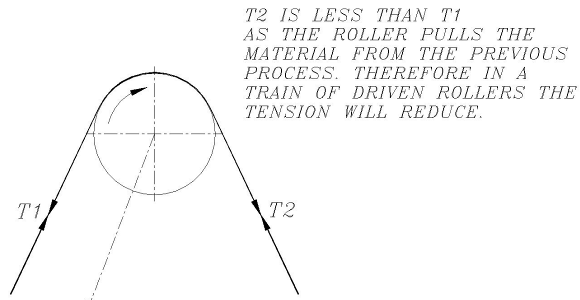
There are at least three main causes of tension changes in the transportation section of a web processing machine, these are differential roll surface speed, roll friction and film shrinkage.

1. ***DIFFERENTIAL ROLL SURFACE SPEED***. This is a major source of tension change and is usually a fault in the design of the equipment. Tension is generated when the forward nip rollers (B) are running at a slightly higher surface speed than the preceding nip rollers (A), as shown.



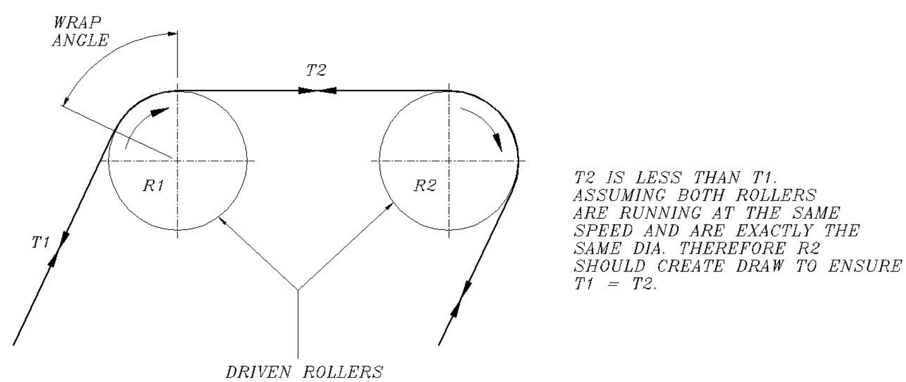
Tension generated in this manner is referred to as 'draw'. This technique is used in many instances to create a differential tension in various zones within a machine. It should be noted that the amount of draw in a machine is extremely critical. This principle is useful and can be adjusted by varying the speed of one set of draw rollers using various drive control techniques. However, within a tension zone, when driven rollers are incorporated, often unwanted tension variations can be created and therefore driven path rollers within a section have to be precisely manufactured to optimise the tension profile within that section.

A free running path roller will create tension in a different way to a driven roller. When a transport system incorporates driven path rollers, the infeed tension will always be greater than the outfeed tension assuming the roller is pulling the material from the previous source.

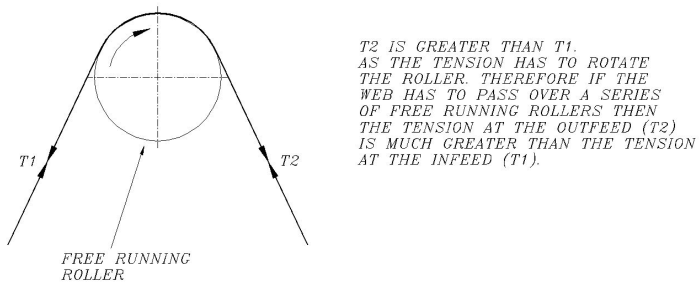


DRIVEN PATH ROLLERS

It is therefore necessary to introduce draw into the upstream path rollers to ensure tension is maintained at a constant level at all times. This is an extremely **difficult** design feature and has to be treated with the greatest of care.



DRIVEN PATH ROLLERS



NON DRIVEN PATH ROLLERS

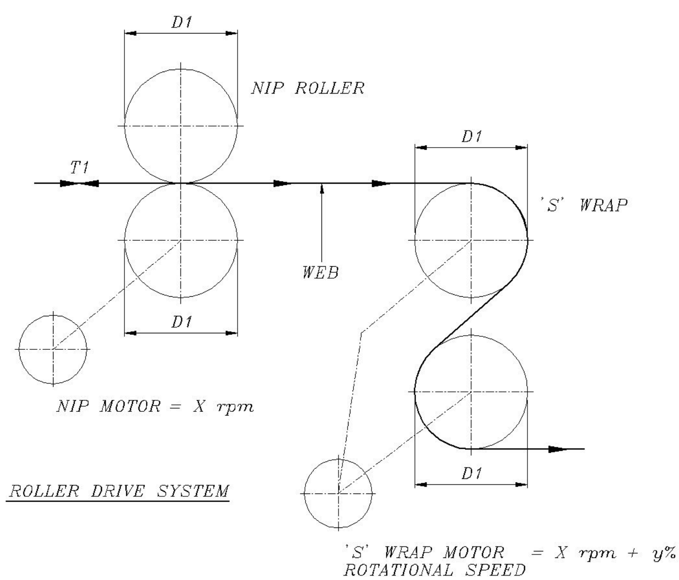
Conversely, when you have path rollers which are free running, it is imperative that these rollers are easy to rotate especially when processing thin materials of narrow width.

The tension on the outfeed of a free running path roller is always greater than the infeed tension, therefore, if you have multiple numbers of free running path rollers, the tension upstream is always much greater than the tension downstream. You can very soon reach a situation whereby the tension downstream can be zero and the tension upstream can be quite high, this is due to an excessive number of free running path rollers not rotating freely. Therefore, it is always a disadvantage to have many free running path rollers in a web transport system unless they are designed to rotate freely. Air bearings are always a solution to reducing friction for fixed web width material processing.

2. ***ROLL FRICTION***. This is the drag on the web created by idler or free running rollers. Any idler or non-driven roller which is rotated by the web passing around it will increase the web tension since it is necessary to impart a force onto the roller to cause it to rotate. In driving the roll by the web, the web must overcome the friction of the idler roll bearings and must also provide any torque to the idler roll during acceleration and deceleration. All idler rolls should be supported on small diameter ball bearings to reduce the amount of force necessary to cause them to rotate. The rollers should also have very low mass to reduce the forces generated by the roller when rotating at high speed. Conversely, a driven roller will reduce the web tension assuming there is sufficient traction between the roller and the web and the surface speed of the driven roller is at least equal to the web speed. This is one reason why draw should be introduced within a driven section of a machine to ensure that the web tension is maintained at a constant value between each of the driven rollers. The diameter of the roller and the degree of overspeed created by these rollers is critical to optimise and maintain the level of tension within each section of a machine.

3. ***Effects of Tension***. Tension is necessary to efficiently unwind and transport a web through a process and then rewind the web into a reel or spool. The tension level requirements can and do change within a process when transporting and rewinding material. It is, however, the tension level extremes, both high and low, which cause web handling problems. Tension levels which are too low will contribute to wrinkling and poor tracking of the material as well as poor register and, in a rewinding process, telescoping of rolls due to the amount of air entrapped between the rewinding layers. Excessive tension contributes to stretching of the material which creates creasing and distortion of the material. From a rewinding point of view, cores can be crushed and rolls will block stiction between rewinding layers and star due to excessive tension. When combining two or more webs during a laminating operation, it is of paramount importance that both webs are laminated at the same tension (extension). In the event of one web being adhered to another at differential extensions, then curl will take place in the finished laminated material. Tension control is one of the most important features in any laminating process.

4. ***Control of Tension***. The correct operating tension in each section of the web handling process is extremely important. Good equipment design must provide a way of obtaining the correct tension level in each section, i.e. the unwind, the web transport system and the rewind section of the machine. It is also preferred to isolate the tension in each of these zones to optimise the process requirements.



In the web transport system the most common technique used for controlling the tension is by the use of driven path rollers with a section configured as an 's' wrap or as a nip roller.

Tension can then be controlled by means of varying the diameter of the rollers or by having independent drives to each of the rollers.

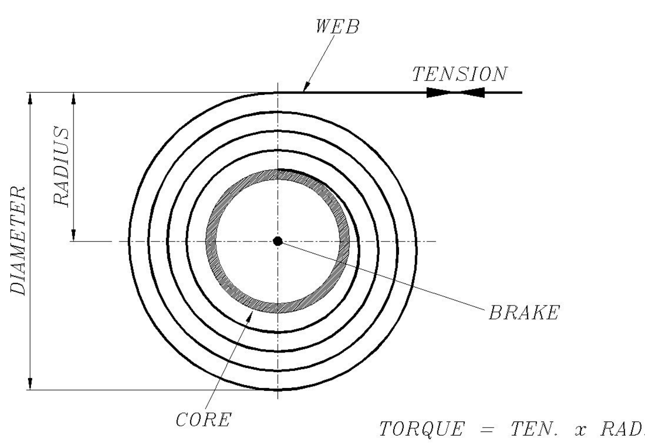
Tension at the unwind of the machine is usually achieved by varying the amount of drag on the unwind reel support shaft. This can be created by a pneumatic brake or an electrical particle brake, whichever is found to be the most suitable for the particular process. An alternative is to incorporate a motor to drive the unwind reel which is the most controllable system as it can operate in both the forward and reverse direction providing drag and forward motion.

The rewind tension on a machine is controlled by the torque transmitted to the rewinding reel, however, rewind tension should be kept to a minimum wherever possible to ensure the material is not distorted or stretched during the rewinding process.

5. ***MEASUREMENT OF TENSION***. To be able to control the tension and to duplicate a previous successful process the tension level must be known and measured *(without measurement we know nothing)*. Tension can be measured by use of a strain gauge or a load cell on one of the roller supports or can be monitored by means of a tension sensing compensating roller system. When using a load cell system, there has to be a change in tension for a change in measured value to take place. Free running path rollers can also provide smoothing to tension changes caused by an unwinding reel. A tension sensing compensating roller system can, in certain circumstances, be a better system as it provides feed forward information as to a potential change in tension. As the tension sensing compensating roller moves it indicates there is going to be a change in tension, there has, in fact, been a change in the length of the material between two points, however, a tension change does not necessarily occur until the roller hits its end stop (this is not strictly true but for a small angular movement of the roller and low inertia dancer it can be assumed to be correct). This type of tension measuring system also has the advantage of providing some forgiveness in the web path and, therefore, certain frequency undulations in an unwinding reel can be compensated for by the roller moving. For a load cell system to achieve the same result, additional costs are incurred.

There is one disadvantage to this technique and that is it requires to have a mechanical force applied to it for the set point tension. Also, the engineering has to be precise to ensure it does not induce any distortion into the web due to the dancing compensating action of the roller. There is no ultimate advantage in defining a tension as a low, medium or high, however, its exact value should be specified and quantified in measurable terms of kilograms per centimetre per micron of web, or Newtons per centimetre of web width per micron of web thickness, it has far more meaning and is repeatable. Typically, unwind tension values are not the most critical but just need to be sufficient to restrain the material during the unwinding process. Transportation tensions, again, are not critical as long as they are sufficient to cause the material to adhere to the rollers during the transportation process. Rewind tensions, however, are of paramount importance and have to be controlled precisely during the winding process. In many instances the rewind tension profile should not be maintained at a constant value due to the pressures generated by the layers of material as the reel diameter increases. Therefore, taper tension profiles are necessary to optimise the winding techniques. The minimum taper tension in a process would be represented by a constant torque at the rewind.

UNWIND SECTION

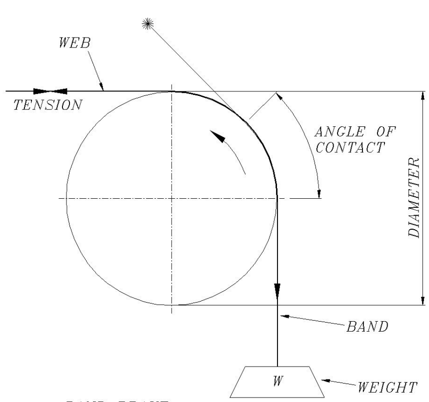


SIDE VIEW OF UNWINDING REEL

A continuous web processing system must begin at the unwind where the material is unwound and then fed into the main process. The main function of the unwind section of a machine is to control the supply of material into the process. Its requirement is to present the unwinding web in such a manner that it is flat, wrinkle free and at the correct tension for the processing section of the machine. The main requirement is to ensure that the tension is optimised and this is achieved by either a braking system or a motor which tends to apply a reverse motion to the unwinding reels. Brakes generate the torque to create the tension by means of mechanical friction or an electro-magnetic force.

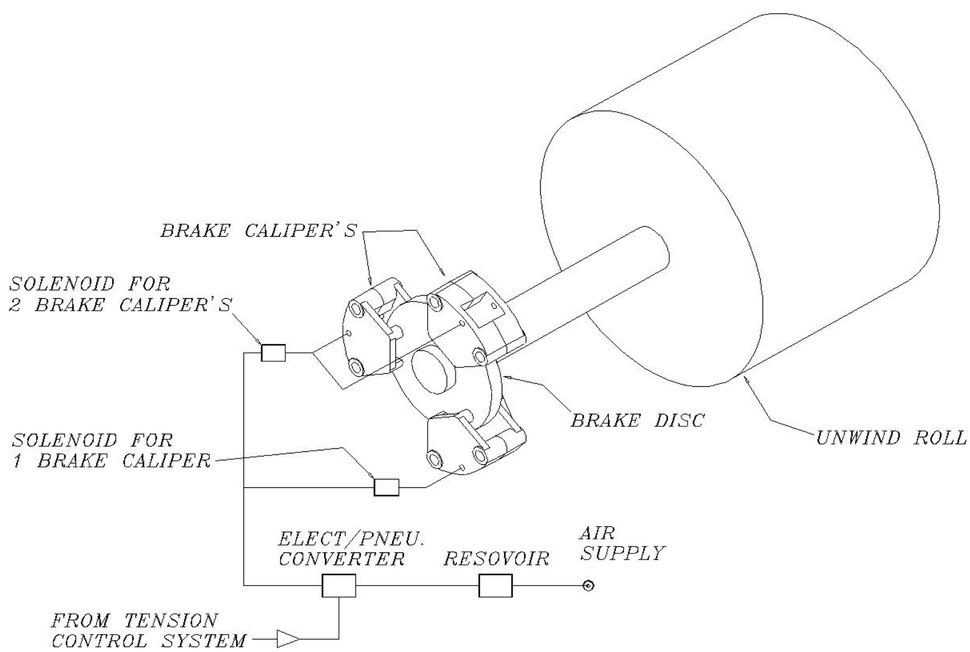
The torque can be regulated pneumatically, electrically or by mechanical means. Torque can be applied to the reel itself via the outside surface of the reel, however, this has a potential disadvantage of causing damage to the material being wound. Reels are essentially energy absorbers, whereas a drive system provides energy into the unwinding reel.

The simplest form of a brake is to use a band or strap acting on the outer surface of the unwinding reel which is then used to cause friction against the surface of the unwinding web. This technique, albeit crude, is acceptable when unwinding a product which will not suffer from damage due to the surface contact of the band brake. The efficiency of this form of brake decreases as the reel diameter reduces since the area of contact reduces as the reel diameter reduces. Unfortunately, heat is generated due to the contact between the unwinding reel and the band of material resting against the surface of the reel which can be a disadvantage to the product being processed. Also, due to the friction between the two surfaces, static can be generated in certain types of material. This technique can be found on old equipment processing products that do not suffer from the surface contact of the band brake and operate at low speeds.



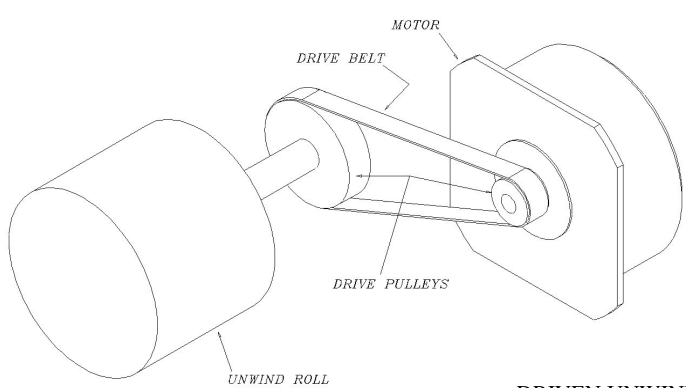
BAND BRAKE

Pneumatic disc brakes or particle disc brakes are a common form of creating unwind tension, but the disadvantage of both these systems is that they can only provide back tension to the product being processed. In the event of the inherent stiction within the system being greater than the required tension, then this technique will not reduce that value and, therefore, the actual tension in the product could be greater than the desired value. However, the principle of a pneumatic disc brake and a particle clutch brake is used extensively and is more than adequate for many processes. However, it is important to incorporate some form of tension feedback to ensure that the effects of inertia created by the unwinding reel are compensated for. An air operated system will not respond as quickly as an electrically operated system, as air is a compressible medium and cannot respond instantaneously. However if the system is designed properly and a local air reservoir is provided prior to the control unit, this will give an adequate supply of air to the braking system quickly to ensure that the response time is at an acceptable level. It is also important when using a pneumatic disc brake with calipers on an unwind tension control to have sufficient calipers to provide the maximum desired unwind tension. There should also be the capability of switching out calipers to ensure that the control system is operating at an acceptable value when creating the desired minimum tension.



It is important that the diameter of tube between the electro-pneumatic converter and the tension calipers is as large as possible and that the length between the electro-pneumatic converter and the calipers is kept to a minimum. The response time for a process where one metre of tubing of say 6 mm diameter is used between the control system and the pads could be hundreds of milli-seconds and, therefore, it is important to keep this length as short as possible. It should also be remembered that there is a significant difference between the static and dynamic torques created by most disc brakes and this should be taken into account when any calibration takes place. As far as electrically operated, magnetic particle and friction type brakes are concerned, again these suffer from a response lag time due to the inductance of the coil used to create the magnetic force. This delay tends to be in tens of milli-seconds as opposed to hundreds of milli-seconds. Another disadvantage with an electro-magnetic system is the hysteresis which is the magnetic hysteresis created within the system causing a dead band in its operation. There is also a disadvantage in that if the tension range required from the system is high, then you will have a problem with the minimum tension level available from the unit which cannot be switched out by using the techniques advocated previously for the pneumatic system.

Motor powered unwinds are the best solution as they overcome all the above disadvantages as they can create both forward and reverse motion to the unwinding reel. The only disadvantage as far as the driven unwind is concerned is the cost, the performance benefits are enormous.



DRIVEN UNWIND

The design of the unwind tension control system should be such that it can maintain the tension in the unwinding web at a constant value at all times. This tension should be as low as possible and still maintain flat web control. Low unwind tension is particularly important when processing extensible materials such as polyethylene. Maintaining a constant low tension will reduce stretching, curl and damage to the material and, in particular, register control of the product in the final process. The actual value of the unwind tension is not as critical as other sections in the process, however, its consistency is of paramount importance. Basically, the tension in the unwinding reel should be set to the minimum value possible to provide the necessary flat presentation of the web to the next part of the process.

There are two forms of tension control, manual and automatic. If a manual tension control is incorporated into the process, it is necessary that the torque in the mechanism used to control the unwind tension is adjusted as the reel diameter reduces. From the basic formula, *tension is equal to torque ÷ reel radius*, it can be seen that as the radius reduces, the torque has to reduce to maintain the tension at a constant value. Using a reel diameter follower to control the change in torque relative to diameter is adequate for slow processes or processes where the unwind reel diameter change is minimal. However, in most up-to-date processes the unwind reel diameter change would typically be in the range 10:1 (i.e. 800 mm diameter to 80 mm diameter). Therefore, the changes in torque would have to be a 10:1 to maintain constant tension, which is not difficult to achieve, however, if the speed range of the machine is say 10 metres per minute to 300 metres per minute, 30:1, then the changes in inertia generated by the reel are enormous and, therefore, it is necessary to have some form of dynamic tension control. This can be achieved by the use of either a load cell or a tension sensing compensating roller in the control loop, as previously described.

The output from this tension measuring system is then fed to the control system and can compensate for any variations in reel diameter or web speed by monitoring the changes in web tension.

PROCESSING SECTION

The web should enter the processing section wrinkle free, flat and in the correct position to ensure that the next part of the process can provide the necessary requirements. It is also of paramount importance that it enters the processing section at a constant tension. The tension control in the processing section should be positive and should provide isolation between the unwind and rewind section of the process. In many instances it is necessary to have multiple tension zones within the processing section, depending on the different processes implemented. There are a number of guidelines which should be considered when trying to optimise the transportation of a web through the processing section of the machine.

1. The minimum number of transport rolls should be incorporated in the process, whether they be driven or non-driven. Excessive use of transport rolls can contribute to either higher or lower tension levels, depending on whether they are non-driven or driven. They can also contribute excessively to damage to the material if the non-driven rollers are not rotating at the correct speed. Additional rollers also increase the cost of the equipment and service costs, as any mechanical piece of equipment is prone to wear.

2. The unsupported web path between rollers should be kept to an absolute minimum. Typically, an unsupported web path should never be greater than the width of the product being processed. This, of course, is impractical when processing webs of tens of millimetres in width, however, the above is a reasonable rule of thumb when processing product of width 500 mm and above. Excessive unsupported web paths will tend to create wrinkles and distortion in the web. It will also induce tension due to the catenary created by the web between the rollers.

3. Transport rollers in a process, wherever possible, should be driven rollers with the maximum angle of wrap possible. This is particularly important as the thickness of the material reduces as it is not possible for the thinner materials to impart the necessary torque onto a non-driven roller. However, the disadvantage of using driven rollers is that the diameter of the rollers must be maintained accurately, otherwise variations in tension will take place between two driven rollers. Typically, a roller having a wrap angle of between 90° - 180° should have an accuracy of ±0.03% in its diameter.

4. In the event of it being necessary to use non-driven rollers, then it is important that these are supported on low coefficient bearings of the smallest diameter possible. The rollers themselves should be manufactured from a lightweight material and the angle of wrap of the material around the rollers should be the maximum possible. Free running rollers must be dynamically balanced to ensure that they do not impart any inconsistent forces onto the web while they are rotating.

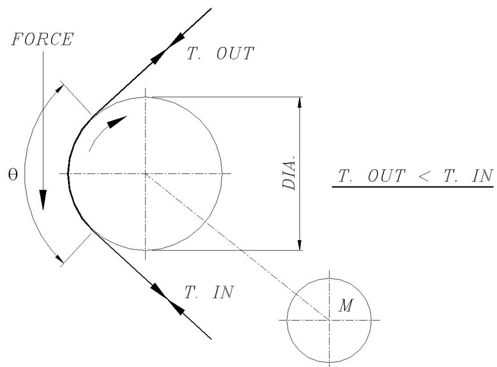
5. All transport rollers within a machine, whether they are driven or non-driven, should run concentric and parallelism between the rollers should be as accurate as possible. Typically, the total misalignment between any two adjacent rollers should not be greater than 0.03 mm per 500 mm of roller length. All rollers should be concentric within 0.05 mm TIR.

SPREADER ROLLS

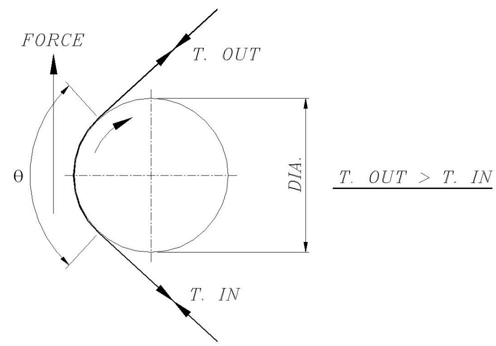
Quite often spreader rolls are used to remove any wrinkles from a material as it leaves the unwind section of a machine. Spreader rolls can usually minimise wrinkles but cannot remove a fold once it has been created in a product. There are a number of commonly used types of spreader rolls, these consist of a bowed roller, a spirally grooved roller or a roller which has an elasticated sleeve fitted to it causing spreading of the material as it is transported round the roller. It is important that all these rollers are positively driven at web speed for optimum operation. It is important that discussions take place at the design stage between the manufacturer and the supplier of these types of rollers to ensure that the correct wrap angle is provided as this is critical to the optimum operation of any type of spreader roller. Often grooves are machined into driven rollers to try and provide some degree of spreading of the material and the possible removal of air between the layers of material and the roller to prevent the material from creasing or sliding on the roller during transportation.

TRANSPORT ROLLERS

As previously stated, the wrap angle should be as large as possible to prevent slippage between the material and the roller itself.

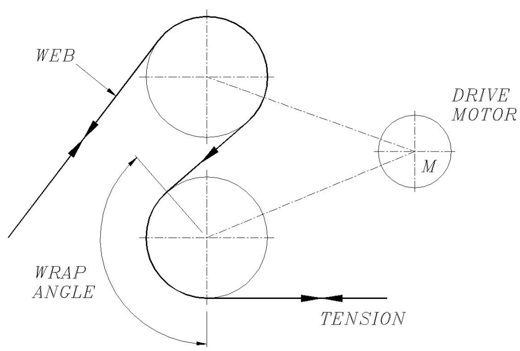


DRIVEN ROLLER

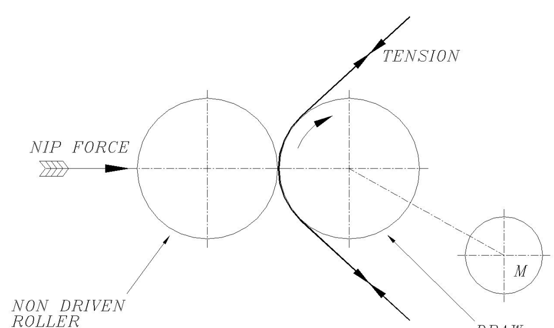


NON-DRIVEN ROLLER

As far as the nip roller is concerned, the nip force applied to the material will not change the power required to rotate the nip roller unless the force is such that it causes deformation to the nip roller surface itself. However, the nip roller does provide an increase in the coefficient of friction between the surfaces of the draw rollers and therefore improves the transportation capabilities of the driven draw roller.

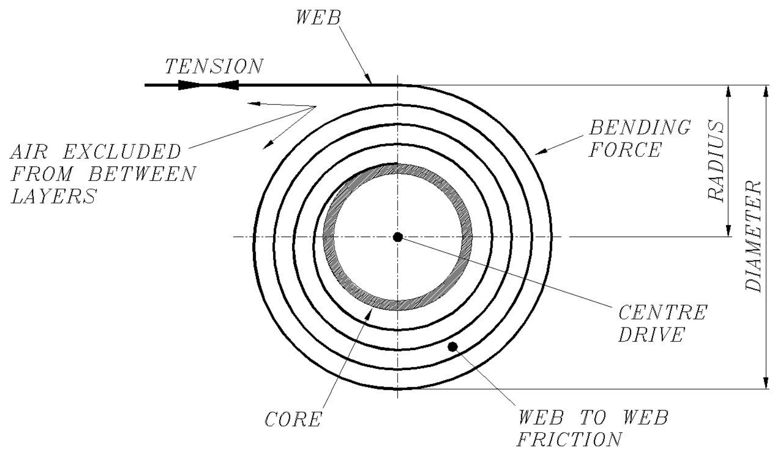


'S' WRAP



NIP ROLLER

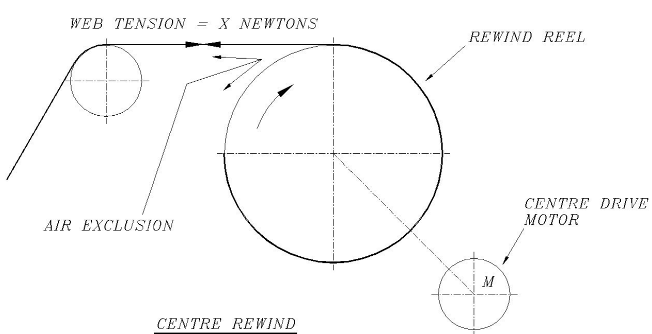
REWIND SECTION



SIDE VIEW OF REWINDING REEL

The final stage in any processing operation is the rewinding of the converted web which is the most important and critical part of the process. It is the final step in the process and it converts the flat web into a reel. The requirement of any rewinding process is to wind a reel at the lowest tension possible, but at a density which will allow it to be transported from one location to another without damage or telescoping taking place. There are three basic principles of winding, centre wind, surface wind and centre surface wind.

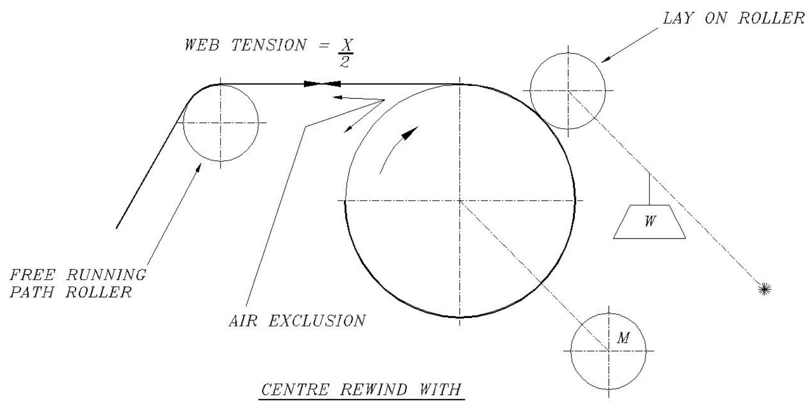
CENTRE WINDING



CENTRE REWIND

Centre winding is provided by delivering all the winding power to the centre of the rewinding reel. This is the most commonly used method of winding thin materials.

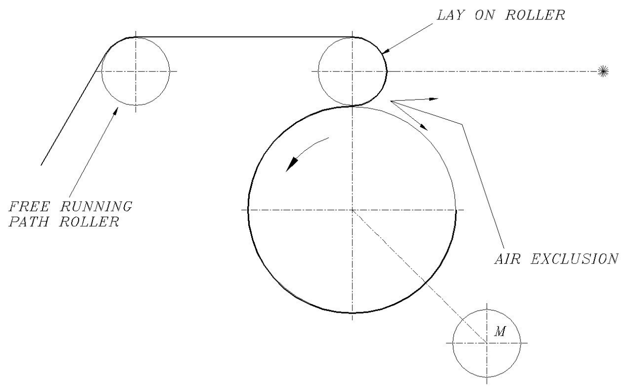
The disadvantage of a centre wind system is that you have to transmit the tension to the web from the centre torque of the winding reel and, therefore, if it is that material has to be wound at a relatively low tension and low reel density, then the disadvantage is that you will screw the reel and cause damage to the material at the core. There are additional techniques that can be incorporated when centre winding which include the use of a lay-on roller that is in contact with the rewinding reel to improve the winding.



CENTRE REWIND WITH LAY ON ROLLER

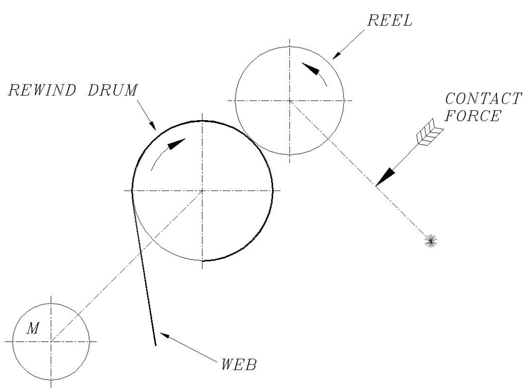
This lay-on roller is not driven, but is used to exclude the air from between the layers of material during the winding process.

The contact force of this lay-on roller should be adjusted in proportion to reel diameter and web speed and the degree of variation in contact force is dependent upon the particular material being processed. When processing some adhesive or foam products, a contact force between the reel and the lay- roller is undesirable and, therefore, a technique know as gap winding should be incorporated. Essentially, gap winding ensures that the unsupported web between the last roller before the rewind and the rewind reel itself is kept to a minimum. This ensures that no distortion takes place in the web after it leaves the last roller and before it enters the rewind reel. When winding a web without the use of a lay-on roller, typically a tension of x is required. When a lay-on roller is used in the process this tension can be halved and if the web is wrapped around the lay-on roller during the winding process, then the infeed tension can be typically one fifth of the tension required without a lay-on roller, to achieve the same density of reel. This is because of the air exclusion and the nip induced tension at the point of rewind.



These figures vary, dependent upon the particular material being processed, however, they indicate the way tension in the rewinding web can be reduced by the use of a lay-on roller.

SURFACE WINDING

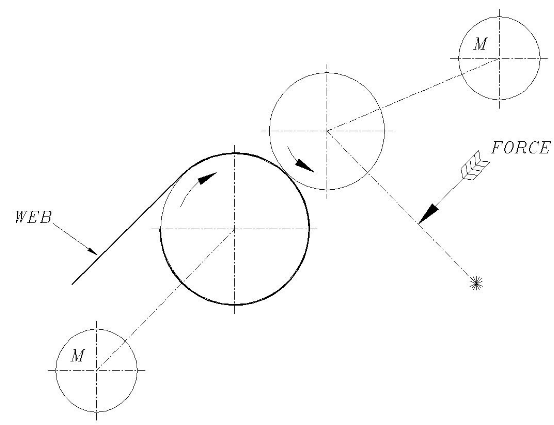


SURFACE WINDING

Surface Winding is provided by allowing the rewinding roll to ride in contact with a driven roller. The torque to the rewinding reel is supplied by the driven roller and contact between the driven roller and the rewinding reel. This method is used extensively in the paper industry, but is not normally used for webs of thin films running at high speed. Surface winding is also unsuitable for processing foam materials or adhesive materials. It relies on the contact force between the rewinding reel and the driven rewind drum.

The density of the finished reel can be changed by varying the surface overspeed of the rewind drum and the contact force between the rewinding reel and the rewind drum. However, the material must be of a type that will not suffer from heavy contact forces. Surface winding is particularly useful when processing narrow widths of material (25 - 100 mm), however, wide widths can be processed using a surface winding principle as long as the web speed is slow. Surface winding is often used on a polythene extruder where the quality of reel is not of paramount importance.

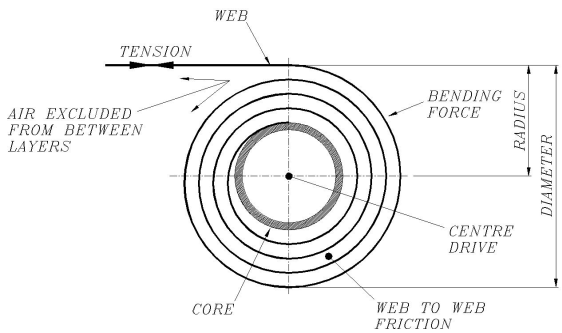
<u>CENTRE SURFACE WINDING</u>



CENTRE SURFACE WINDING

Centre surface winding is, in many cases, the most sophisticated and superior method of winding. It utilises both the techniques of applying tension to the material by means of a centre drive as well as driven surface contact with the reel. This technique is the most versatile as you can vary the contact force, the centre wind torque and the draw created by the rewind drum.

REWIND FORCES



SIDE VIEW OF REWINDING REEL

The total force or torque required to wind a reel of material is essentially composed of four different force components. The force components are required to:

a) Bend the material, allowing it to be wound into a roll.

b) The web tension required to exclude the air from between the rewinding layers.

c) The actual tension in the material.

d) The force required to provide the necessary web to web friction.

The sum of all this is commonly known as the Wound-In Tension (WIT).

The tension in a reel is created by the combination of the centre torque, the nip contact force, if used, and the web tension as it enters the rewind. This can also be affected by the speed that the machine is running at. This is often termed as the TNT's (Torque, Nip, Tension and Speed). The result of all these forces creates a reel and the tension in that reel is referred to as the wound-in tension. The density of the reel is defined as the wound-in density. The main basic winding principles are centre wind, surface wind and a combination of the two, centre surface wind. Since it is that reels can be wound using a surface winding principle only, it can be seen that tension can be induced into the reel via the nip contact force. Reels can be wound with zero web tension and a nip contact force only, therefore, nip induced tension is a major factor when rewinding material.

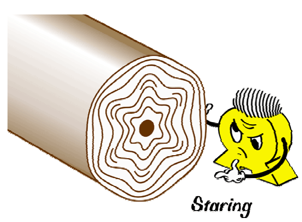
Extensive research has taken place into determining the nip induced tension and even today this is not fully understood, however, one thing is definite and that is tension can be induced into the reel by the nip contact force and the deformation that takes place in either the nip roller or the reel during the winding process. This nip induced tension takes place on the top layers of the material between the top few layers of the material during winding.

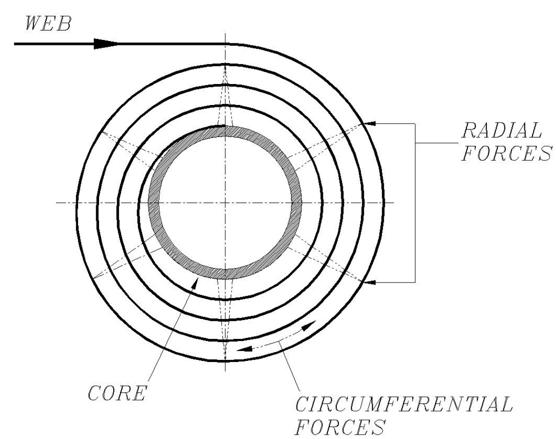
The force required to bend the web into the format of a reel when dealing with thin, flexible materials is negligible in comparison with the total force requirements. However, since the stiffness of the web varies with the cube of its thickness, this force can be significant when dealing with thicker webs. Since the principle requirement is to wind a web at the lowest tension possible, then the force required to provide the web tension is also relatively small. Although it is small it is extremely important as, without it, control of the web will be lost and it will wander at the rewind section of the machine.

The force required to exclude the air from between the rewinding layers is typically the largest force component for very thin filmic webs, especially when processing at high speeds. The amount of air carried into a reel by the surface of the web depends upon the width of the web, the speed of the web and the distance the air must travel from the contact point. Wide webs at high speeds and large roll diameters entrap more air and thus require more force to expel the air. Entrapped air can be useful as it does act as a lubricant between the layers of the material, however, this allows the film to slip on itself and an excessive amount of air in a reel will cause a soft roll and ultimately telescoping will take place.

The use of a lay-on roller, as described earlier, can significantly reduce the amount of infeed tension required in the material to exclude this air and, therefore, the benefits of a lay-on roller in centre winding or centre surface winding are substantial. The force required to overcome the web to web friction is the frictional drag between the layers of material. If the air has been removed from the reel prior to the winding process, then the layers of material can make contact with each other and hold them in place. If a lay-on roller system is not incorporated, as the roll is winding tension must be maintained for many layers to allow time for the air between the layers to escape. However, if the web to web friction is high, the tension may decrease before the air can escape. The lay-on roller or contacted roller will also induce tension into the top layers of material during winding, this is commonly known as Nip Induced Tension (NIT).

The rewind tension profile is of paramount importance. Typically, rewind infeed tension can vary between a constant tension to a constant torque profile. A constant torque being the maximum rewind taper tension profile. However, the rewind tension should never increase as the reel diameter increases. The rewind tension requirements depend upon the physical characteristics of the material being rewound, however as previously stated, the primary objective should be to wind a reel with the lowest possible tension, but at a density to allow it to be transported without telescoping. The desired tension will vary significantly depending upon the particular material being processed, however, as a guideline the rewind tension will be approximately 10 - 25% of the elastic limit of the material being processed. If a reel is wound under a constant tension profile, depending on the particular material, the circumferential forces created as the reel diameter increases are enormous and can cause excessive damage to the finished reel.





This is often shown by starring in the edge of the reel. If it is that a constant tension is required for the particular process, then the torque required by the centre wind drive will have to increase as the diameter increases. Constant tension winding is typically only used when processing paper products. When processing flexible packaging and extensible materials, then a taper tension profile is normally used.

Radial and circumferential forces are created by the layers of material as the reel diameter increases. These radial forces can be so high that once the reel has been removed from the winding station, the core can crush due to the fact that the external forces are so high. When processing thin materials, these radial forces are so great that they will actually cause the tension in the lower layers of material to pass through zero into a state of compression.

As these compression forces increase and overcome the frictional force between the layers of material, the complete reel will slip and buckle on itself. For this reason a taper tension profile is typically used when winding high elastic modulus material such as polyethylene, polyester and polypropylene.

A constant torque profile which is the maximum taper tension that is incorporated into a winding process will create a reel having reduced circumferential forces as the diameter increases. However, depending on the diameter of reel being wound, the tension at the outer layers of material can become so low that the reel will not wind with an exact edge profile, therefore, the degree of taper tension in a winding process is related to the material being processed and the diameter it will be wound to. Typically, if winding a reel between 76 mm and 500 mm then the tension could be reduced by 50% during the winding process without losing registration of the rewinding reel. It is always better to start the winding of a reel from the largest possible diameter core, since the rewind tension change between 75 mm and 150 mm is far greater than the rewind tension change between 150 mm and 500 mm. When winding on small diameter cores such as 70 mm and 76 mm cores, it is often necessary to start the wind with an excessive level of tension to ensure that the reel does not telescope when it is wound to the required maximum diameter. However, taper tension is a useful tool in controlling the quality of the rewound reel.

REEL DEFECTS - CAUSES AND CURES

There are many causes of reel defects and to try and create an orderly representation of the various defects the following has been split into five sections, these being unwinding, tension control, slitting, web transport and rewinding. This section will continually expand, however, the various defects will be split into the five sections described above. It is essential that all operators and managers within a department associated with the processing of a continuous web have a full understanding of the problems that can occur, the cause of these problems and how they can be rectified. It is of little use to increase the tension in one part of the process which will cause a defect in the finished reel. "Two wrongs never make a right". The following pages of information can be used as a reference to assist with achieving the optimum processing characteristics and will hopefully assist in recognising the cause of the defects.

One of the most fascinating and stimulating areas associated with the production and research of optimising the production of finished reels of material is to understand the causes of the problems that occur in the reels and how they can be resolved. The control of the rewind reel density is of paramount importance and, therefore, rewind tension control is one of the main areas that needs to be monitored.

The unwind tension is critical, but is not as critical as the rewind tension. The transportation tension through a process, as long as they are constant and adequate, will not cause any distortion to the web during the transportation process. The slitting of material can also cause roll defects, which are shown below.

UNWINDING

The principle of unwinding is to transport the material from a reel to the process. It is essential when unwinding materials that the tension in the material is kept at a constant value at all times. It is also important that the material enters the process flat and free from wrinkles. Unfortunately, reels that are being unwound typically are not round and therefore tension perturbations take place during the unwinding process. The actual value of the unwind tension is not always as critical as the fact that it must be maintained at a constant value at all times. It is therefore important to introduce some form of tension control at the unwind of the machine and also measure the unwind tension throughout the unwinding process.

The unwind tension can be measured by a tension sensing compensating roller, sometimes referred to as a dancer, or by a load cell. The position of the tension measuring device is of paramount importance and the design, if it is a dancer, is extremely critical. Tension changes caused by the unwinding reel can, in certain instances, be removed by the action of a tension sensing roller or, alternatively, if the web passes round a number of non-driven rollers these will also provide function as a dancer as far as tension smoothing is concerned. The unwind tension is controlled by either a brake or a motor which is used to drive the unwinding reel. Brakes are energy absorbers, while motors are energy providers. Depending on the process, a simple brake system is more than adequate, however, for high speed low tension application, a driven unwind is the optimum.

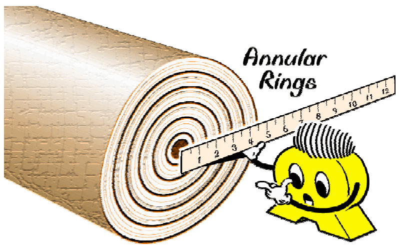
TENSION CONTROL

Tension control is the most important parameter in a continuous web handling process. Tension at the unwind section of the machine has to be maintained at a constant value at all times. Tension throughout the process may vary, however, it must be maintained at a constant value at each individual part of the process, irrespective of what the value is. At the rewind section of the machine, wound-in tension at the reel is extremely important as this is the final product that will be shipped to the ultimate customer. Tension can be controlled in many ways and is described in more detail under each section of the process.

SLITTING

Slitting is the part of a process which changes the width of the material from a wide section to a narrow section. Slitting can be created by various means, however, the principle is to cut the material into a narrower product. Each method of cutting can cause its own problems and will depend on the type of material being processed.

ANNULAR RINGS



Concentric rings or high and low spots on the side of a rewound reel are called 'annular rings'. These are indicative of a well wound product. The first fact to ensure is that these rings are of a regular pattern and not of a random pattern. 'Annular rings' are only when the rings occur in a regular pattern.

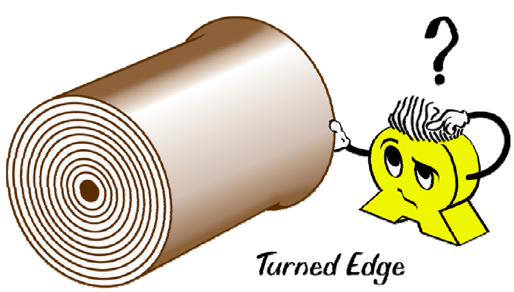
When these rings appear in a regular pattern and are approximately 0.1 - 0.2 mm in depth, the cause can typically be traced to a slitter knife run-out and this can be corrected by regrinding the knife edge. The knife edge, typically, has 'wobble' causing an irregular slit width. This wobble on the knife causes a weave in the material during the winding process and this will ultimately appear as evenly spaced annular rings on the side of the rewinding reel. When this wobble occurs in the female, shear cut, slitting knife the first annular ring will appear at a diameter equal to the diameter of the female shear knife, assuming that the female knife is running at line speed. If it is that the speed of the female knife is greater than the web speed, then this differential in speed will have to be taken into account in relation to the diameter of the first annular ring. The second major ring will appear at twice the diameter of the knife minus the percentage of overspeed on the knife if there is one and the third at three times the diameter and so on. If slitting is taking place with crush cut knives, then the wobble in the slit edge or deviation in the slit edge will be created by the crush cut top knife. Therefore, the first annular ring will occur at the diameter of the crush cut knife itself. The second annular ring will be at twice the diameter and the third one at three times the diameter of the crush cut knife and so on. It is also possible that minor annular rings will appear between the major rings and these will become more pronounced as they occur closer to the major rings.

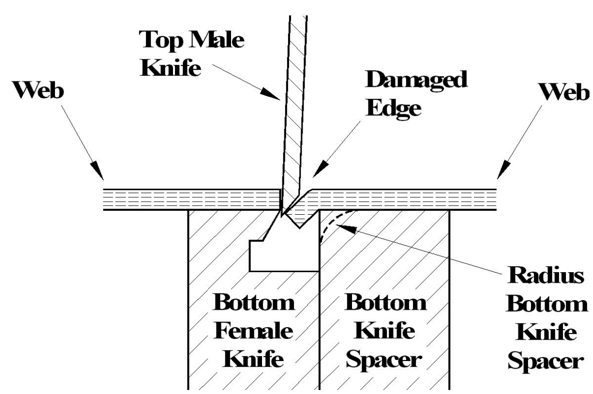
As previously stated, the annular rings are only apparent when superior winding quality takes place. It is, therefore, indicative of a well registered edge profile reel. To remove these annular rings it would be necessary to achieve a better quality knife or knife assembly to reduce any wobble that takes place. The annular rings are not detrimental to the next process as it is only created by the slight inaccuracy of the slit edge. Knives which have wobble in them or knife assemblies which are badly engineered causing side lay in the knife assembly during the web transportation process can also cause this effect.

If it is that annular rings are detected in the rewound reel, then attention should be made to the slitting section of the machine to ensure that there is no end float in the assembly and/or that the knives are not poorly ground.

TURNED EDGES

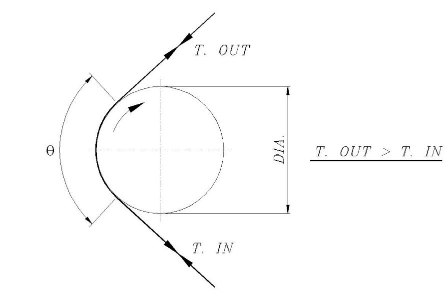
A turned edge occurs on a finished roll when the slitting section of the machine is poorly implemented. When shear cut slitting, one edge of a reel is always supported whereas the other edge, if the top knife has excessive penetration, will be pushed into the space between the shear top knife and the shear knife female bottom knife spacer. One side of the web is always supported and the other side of the web is not supported. Depending on the type of material being processed, this penetration will cause a crease or damage to occur on one side of the reel which, when wound, will cause a turned edge on the rewind reel. This phenomena can be reduced by using double bevel top knives and therefore reducing the amount of penetration of the web into the gap during the slitting process. As an additional help, the adjacent bottom knife spacer can have a radius machined on to it which will then reduce the damage to the web as it is forced into the space between the knife and the adjacent spacer. Ideally, the minimum amount of penetration possible between the male and the female knife will reduce this effect and ideally, the penetration should be no greater than 0.2 mm, however, this means that the accuracy of both the male and female knives and the support shafts have to be of the highest standard possible.



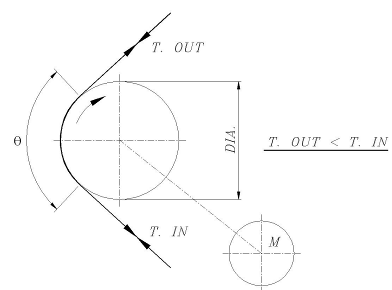


***W**EB **T**RANSPORT*

The web transport system is normally a series of rollers which carry the web from one part of the process to another. These rollers, or bars, can be static or rotating, depending on the particular product being processed. If they are rotating rollers, these can be rotated by the web passing over the roller or they can be driven by a separate motor. Rollers which are driven by the web will induce tension into the web whereas rollers which are driven by a separate motor will cause the web to relax as it leaves the roller. This, of course, assumes that the web is moving at the same speed as the roller.



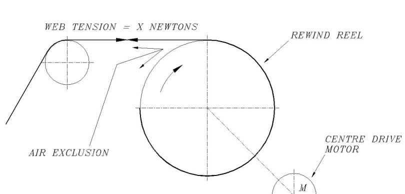
NON-DRIVEN ROLLER



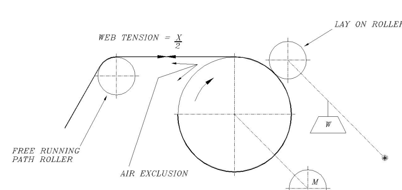
DRIVEN ROLLER

***R**EWINDING*

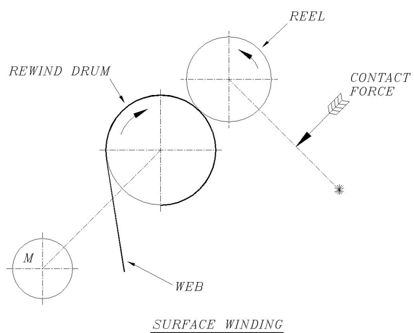
Rewinding the web is the final part of a continuous web handling process. The wound-in tension of the finished reel is of paramount importance and has to be controlled precisely. The actual characteristics of the winding depends on the particular type of material being processed. The effects on the rewind tension are commonly known as the TNTS (Tension, Nip, Torque and Speed). Each of these components can dramatically affect the finished roll and have to be controlled independently to optimise the rewound reel. Extensive research has taken place to optimise the wound-in tension (WIT) in order to optimise the finished roll. The winding principles that are available are centre winding, surface winding and a combination of the two, centre-surface winding. In general, when centre winding a nip roller is provided to exclude the air and induce tension (NIP - Nip Induced Tension) in the rewound reel.

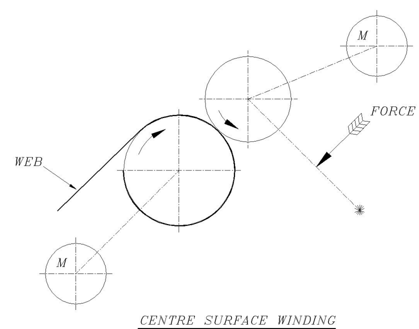


CENTRE REWIND



CENTRE REWIND WITH LAY ON ROLLER





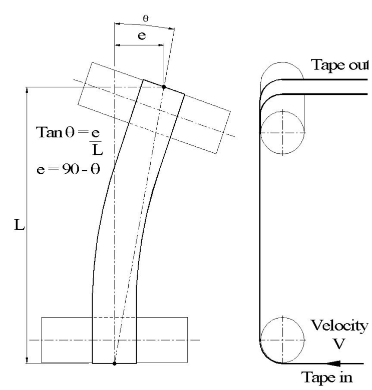
FUNDAMENTALS OF WEB AND TAPE TRACKING

When a web or tape passes through a process, it will be conveyed through the process by making contact with rollers. It is of paramount importance that the axis of these rollers are parallel to ensure optimum web alignment through the process. To this end, it is important that the fundamental law of web tracking is appreciated. This law states the following:

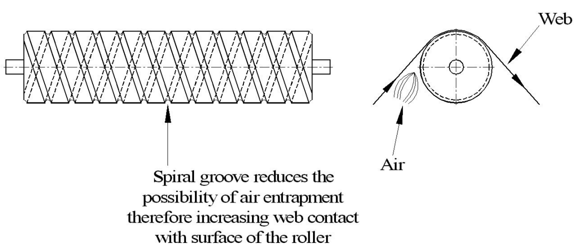
'A web will always seek to align itself perpendicular to the axis of the roller it is approaching assuming that there is continuous traction between the web and the roller.'

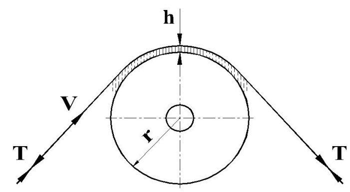
This fundamental law is sometimes stated as:

'A web seeks normal entry to the roller it is approaching.'



However, the basic law of web alignment to a roller will only apply if the web makes sufficient contact with the roller causing the web and the roller to rotate at the same speed. You will often see rollers where the surface has spiral grooves machined into it. Depending on the depth of groove and the configuration, this will have **no effect whatsoever in spreading the web**, however, it will allow the entrapped air between the web and the roller face to escape, therefore promoting traction with the roller. For this purpose, the grooving of a roller will be beneficial. This principle of grooving also means that you create many roller edge effects between roller and material, again promoting the removal of air between the web and the roller surface.





Air entrapment by a moving Web

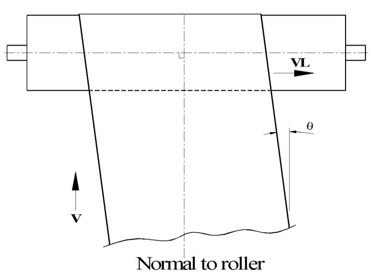
$\frac{h}{r} = 3.407\,(\mu\, V/T)^{2/3}$ for a dynamic roller.

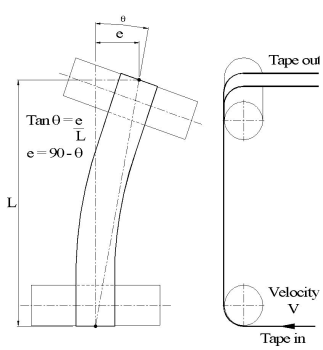
$\frac{h}{r} = 2.146\,(\mu\, V/T)^{2/3}$ for a static bar.

μ = Viscosity of Air

WEB BEHAVIOR AS IT ENTERS A ROLLER

If we assume that a web enters a roller at an angle theta and assuming that the roller surface velocity is *x* metres per second, then based on the fact that the web will try and align itself to the normal of the roller, the lateral velocity of the web will be *VL* metres per second. Again, this assumes that the web is making contact with the rollers such that the web and the roller surface are travelling at the same velocity.



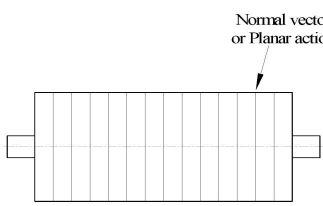


V	=	Roller surface speed and web linear veloci
VL	=	Web lateral velocity metres per second.
Θ (Theta)	=	Web angle misalignment with normal to roller.
VL	=	V (Tan Θ)

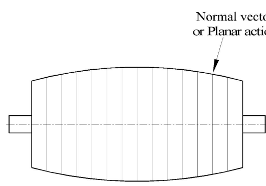
Based on the above, when Theta equals zero, VL will equal zero.

This means that the web will only be laterally static when it is perpendicular to the roll axis. Therefore, if it is required for a web to pass through a process in the same lateral position throughout the equipment, it is essential that all rollers are perfectly parallel.

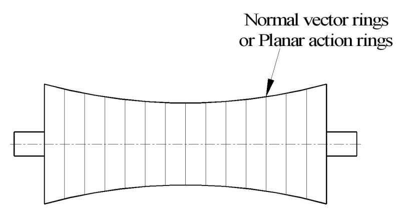
There are three basic roll shapes, a cylindrical roll, a diablo or concave roll and a cambered or crowned roll.



Parallel Roller

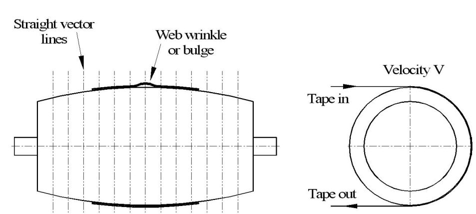


Cambered or Crowned roller



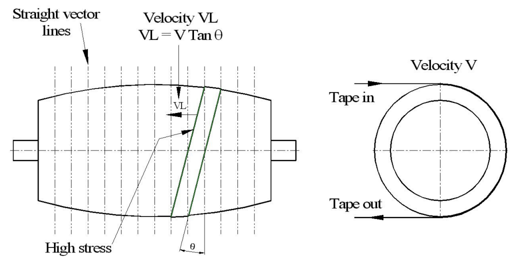
Diablo or Concave Roller

If any of these rollers are rotated and a marker pen is allowed to touch the circumference of the roller while it is rotating, parallel annular rings would be created on the roller. These are known as the normal vector rings or planer action rings. If a tape enters a camber roll, the axis of the tape would not be parallel with the straight vector lines or the normal vector rings created on the roller. Differential stress would be created in the material and it would attempt to align to the natural axis of the roller or the straight vector axis. (Reference should be made to the fundamental law of tracking: *"A web will attempt to align itself perpendicular to the axis of the roller it is approaching"*). Based on this, the tape will climb up the camber until its centre line is on the centre line of the cambered roller. Depending on the width of the material and the size of camber, these high stress forces could create a wrinkle or a bulge in the web on the centre line of the cambered roller. It is therefore important to ensure that the degree of camber and the flexibility of the material are matched to optimise the use of this fundamental principle. Basically, the ultimate as far as this is concerned is that the material would end up with a crease on the centre line of the roller. It is fundamentally incorrect to assume that a cambered roller will create a spreading action of the material. It is completely the opposite to this.

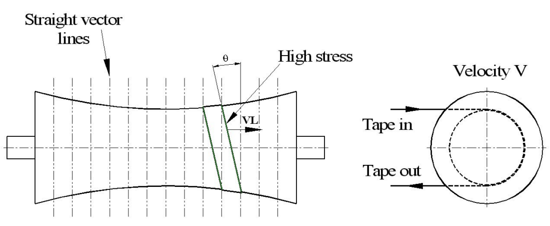


Cambered or Crowned roller

If a tape is allowed to pass around a diablo or concave roller, the opposite action will happen. The tape will tend to ride up the roller and ultimately would traverse over the end of the roller, depending on the degree of curvature on the roller. Basically, the principle is that the high stress edge of the tape is now on the outside of the web and, therefore, will cause the tape to try and twist to the straight vector lines of the roller. If you consider that a tape on entering a roller which is not parallel will tend to have differential velocities at each side of the tape, then this will happen.



Cambered or Crowned roller

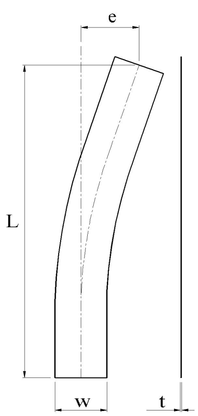


Diablo or Concave Roller

In the case of the diablo roller the outer edge of the material, since it is riding on a larger diameter than the inside edge, will travel at a higher velocity and therefore cause it to ride up the curved surface. This principle is useful in spreading a web, i.e. a small amount of diameter increase at the end of a roller will reduce wrinkles in a web by spreading it.

In both the cambered roller and the diablo roller, the features created by the shape can be used to advantage. With a cambered roller, for a narrow width product, it can assist in aligning the tape to the centre of the roller. With the diablo roller, if a small amount of curvature is applied to the roller, typically 0.3 - 0.5% of the diameter, then this would provide a spreading action to the material and remove creases or wrinkles in the web. However, it must be remembered that the degree of curvature on the roller should be kept to an absolute minimum, ***"more is definitely not better"***. If a diablo roller is used when processing say a 2 mm tape, then this will provide some alignment or tracking of the material as the web cannot align itself to the normal of the roller. The narrow tape will therefore sit in the bottom of the roller shape.

For any of the above to happen, it is imperative that there is continuous traction between the web and roller. Both the web and the roller surface must be travelling at the same velocity. The above also assumes that a web does not have any camber or cast in it. If there is camber or cast, then this has to be removed by the application of tension to the web so that it approaches the roller square and not at a continuous angle. If a narrow tape has cast in it and passes over a cambered roller for the purposes of tracking, then it will align itself offset to the centre line of the web and if the cast is excessive, it will track off the roller.

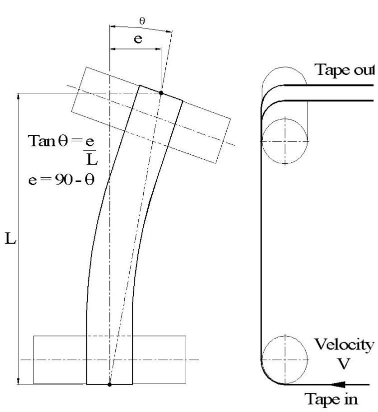


$$TenCr = E * t * e \frac{(W^2)}{(L^2)}$$

E = Modulus (N/m^2)
L = Length (metres)
W = Width (metres)
e = Offset (metres)
t = Thickness (metres)
TenCr = Critical Tension (Newtons)

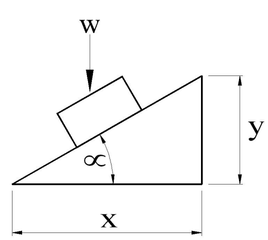
It is essential that this tension does not approach the elastic limit of the particular material being processed. As a guideline the tension that a web should be processed at is between 10 - 25% of the elastic limit of the particular material. Using the fundamental law of web tracking, if two rollers in a machine are not parallel, then by using simple trigonometry you can see how much the rollers are out of line.

This diagram shows a situation where two cylindrical rollers are not parallel to each other, which would cause the web to track off centre. In the event of this happening, by means of basic trigonometry it is possible to determine the angular misalignment between the two rollers.



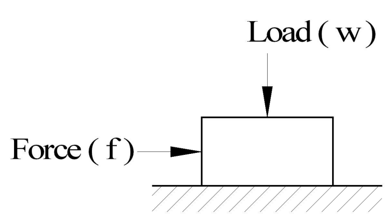
Co-efficient of Friction

The co-efficient of friction μ is equal to the force required to move a body, divided by the weight of that body *w*. The co-efficient of friction is basically independent of area between two surfaces. For a static co-efficient of friction, the force *f* is the maximum force before the body starts to move on a surface. For dynamic coefficient of friction at a given speed, the force *f* is the force required to maintain the body at that speed. An alternative method of measuring the co-efficient of friction between two surfaces is to incline the surface as shown.



$$\mu = \frac{y}{x} \text{ or } \tan \propto$$

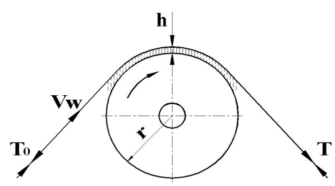
The static co-efficient of friction is the ratio of *Y* divided by *X* when the block just starts to slide down the incline. The dynamic co-efficient of friction is the ratio of *Y* divided by *X* when the block slides at a constant velocity.



$$\mu = \frac{f}{w}$$

<u>AIR ENTRAPMENT BY A MOVING WEB</u>

When a web passes over a rotating roller or a static bar and the contact is only influenced by the tension in the web, then air will be entrapped between the roller surface and the web itself. This is also true when a web is being rewound into a reel.



Air entrapment by a moving Web

$$h = 0.643r\,(6\mu V/T)^{2/3}$$

$$T = T_0 - BVw^2$$

$$V = Vr + Vw$$

μ = The absolute viscosity of air. (0.00018g/cm/sec)

T = The distributed web tension in Newtons/metre.

H = The separation between the roller and the web surface, due to the film of air between the two in millimetres.

Vw = Velocity of web.

Vr = Velocity roller (for a bar 0)

B = Material weight (mass per unit area)

If this roller was then held stationary so that it became a static bar, then the separation between the static bar and the web would be as per the above formula, but Vr roller velocity would be zero.

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