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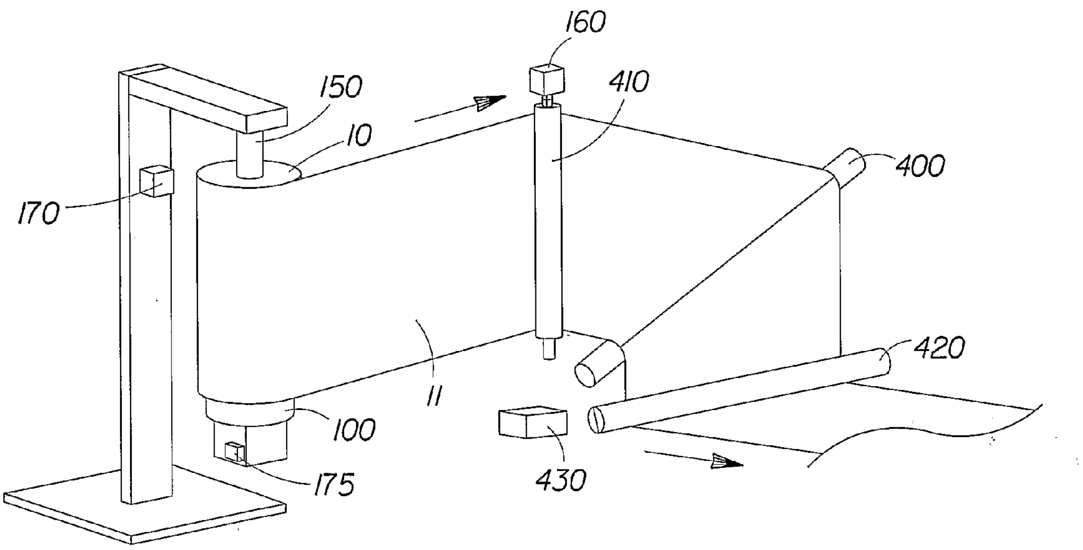
(54) Title: AN APPARATUS FOR UNWINDING ROLLS OF WEB MATERIAL



(57) Abstract: A method and apparatus for unwinding a vertically oriented roll of web material is disclosed. The roll comprises a lower surface, an upper surface and a circumferential surface. The apparatus comprises: at least one drive element adapted to rotate the vertically oriented roll, a sensor adapted to measure a tension of the web, and a controller adapted to adjust a speed of the web according to the tension of the web. The method comprises steps of rotating the roll, determining a desired web tension, and adjusting the speed of the roll according to the desired web tension.

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AN APPARATUS FOR UNWINDING ROLLS OF WEB MATERIAL

Field of the invention:

This invention relates to the handling of web materials. The invention relates particularly to the unwinding of rolls of web materials.

Background:

In the manufacturing of web materials, large rolls of the material are produced. These large rolls are subsequently processed to produce a finished product. The conversion of the roll to a finished or intermediate product requires the transport and unwinding of the roll of web material.

Web-converting processes include a roll unwinding apparatus configured to unwind a horizontally oriented roll to present the web to the converting equipment in a horizontal orientation. A horizontal roll may be core driven; it may be compressed along the longitudinal axis and driven on the end surfaces of roll. The roll may also be driven using belts in contact with the outer surface of the roll. Low-density rolls may be adversely affected by being surface driven. For example, a 250 cm. diameter roll that is 255 cm wide and weighs 1600 kg, may be supported by 5 belts each 15 cm. wide over a circumference arc of 100 cm. This drive produces a compressive force in the supported areas of 20,700 N/m^2. These compressive forces can alter the tissue web's unwinding speed, distort the webs, and lower the quality of the finished products made from the webs.

Horizontal rolls may acquire an egg-shaped cross section rather than the desired round cross section. 15 to 20 cm. eccentricity is common in rolls having a diameter of 250 cm. Unwinding an egg shaped roll is problematic in that the mass of the roll is not balanced about the longitudinal axis. This imbalance results in additional strain on the unwinding mechanism as the forces generated by the rotating roll fluctuate with the unbalanced mass. These forces are directly proportional to the degree of imbalance present in the roll and the speed of rotation of the roll. Severely unbalanced rolls must therefore be unwound slowly to avoid subjecting the unwinding apparatus to destructive forces. Furthermore, the unwinding of the unbalanced roll can cause the speed and tension of the web to fluctuate considerably. These speed and tension fluctuations can result in web breaks and lost production time. Again the affect of the unbalanced roll is more severe at higher speeds so again the unwind speed must be slowed to reduce the incidence of web breaks. The rate at which an unbalanced roll may be reliably unwound limits the rate of the downstream process. The fluctuations in web speed and tension can affect the quality and uniformity of the converted product.

The fluctuations in the web speed and tension also impair the ability of the web processor to splice multiple rolls of material without stopping the unwinding process or without extensive capital investment in splicing equipment to enable a flying splice despite the fluctuations in tension and speed. Splicing methods known in the art require the webs to have matched speeds at the time of splicing. The inability to maintain a consistent web speed thus requires stopping the web and in some instances the entire process to splice rolls together resulting in lost production time.

After a stoppage, the production equipment must be accelerated back to production speeds during which time more productivity is lost. Then the spliced portion of the web must be removed from the finished product. Due to the fluctuations in speed before and after the splice it is often necessary to remove a substantial amount of product to ensure that the spliced portion is removed. This results in high material losses.

This invention provides a method and apparatus for unwinding a roll of a web material that will enable high speed unwinding of the web while maintaining narrow limits on the fluctuations in the speed and tension of the web.

This invention further provides a method and apparatus for unwinding a web that includes a reliable means of splicing multiple webs without stopping the unwinding process.

Summary of the invention:

This invention provides an apparatus and method for unwinding a roll of web material. The axis of the roll is vertically oriented while the roll is being unwound. In one embodiment, the method comprises steps of: rotating the vertically oriented roll of web material; determining a desired web tension; and adjusting the speed of the web according to the desired web tension. This method may be performed on an apparatus comprising a drive element configured to rotate a vertically oriented roll of web material; a sensor adapted to measure the tension of the web; and a controller adapted to adjust the speed of the web according to the web tension.

In another embodiment, the method comprises steps of rotating the vertically oriented roll; determining a desired speed for the web; and adjusting the speed of the web according to the desired speed of the web. This embodiment may be performed on an apparatus comprising a drive element configured to rotate a vertically oriented roll of web material; a sensor adapted to measure the speed of the web; and a controller adapted to adjust the speed of the web according to the desired web speed.

In another embodiment, the method comprises steps of determining a desired tension and a desired speed and adjusting the speed of the web according to the desired tension and /or the desired speed.

In still another embodiment the method comprises steps of: partially unwinding a first vertically oriented roll; preparing a second web from a second vertically oriented roll; rotating the second roll according to the speed of the first web; contacting the second web with the first web; and separating the remainder of the first web from the unwound portion of the web.

Description of the drawings:

Figure 1 schematically shows an unwind apparatus according to the present invention

Figure 2 schematically shows a cross section of an unwind station according to the present invention.

Figures 3a – 3d, schematically show plan views of an apparatus according to the present invention for splicing multiple rolls of web material for continuous unwinding operations.

Figure 4 schematically shows an s-wrap web drive.

Definitions:

Fabric side: the side of a wet laid web in contact with the drying fabric of the web making machinery during the web making process.

Roll: cylinder of web material wound about a longitudinal axis, having a cylindrical circumferential surface, and two end surfaces. A vertically oriented roll has a lower end surface, an upper end surface and a circumferential surface.

Web material: any material having dimension in two orthogonal directions that are much greater than the dimension in a third orthogonal direction.

Unwind station: equipment adapted for rotating a roll of web material in a direction angularly opposed to the direction in which the web is wound about the longitudinal axis of the roll.

Vertically oriented: oriented substantially perpendicular to the plane of the horizon.

By substantially perpendicular it is meant that the vertically oriented object is close enough to perpendicular to the horizon so as to act as an object that is perpendicular to the horizon.

Wire side: that side of a wet laid web in contact with the forming wire of the web making machinery. The forming wire is that portion of a web-making machine upon which the slurry of web-making fiber is initially deposited during the web-making process.

Detailed description of the invention:

Figure 1 illustrates the apparatus adapted to perform the method of the present invention. Rotating drive element **100**, contacts and rotates roll **10**, thereby unwinding the web **11**. The web **11** may be supported by at least one web support element **410**. The tension in the web **11** is sensed by tension sensor **160**. A controller (not shown) calculates the web tension error as the difference between the sensed web tension and a desired web tension. The controller then adjusts the speed of the web **11** to reduce the web tension error to zero.

In another embodiment, the apparatus comprises a diameter sensor **170**, to measure the diameter of the roll **10**. The diameter sensor **170** may comprise a contacting element that maintains contact with the outer edge of the roll **10**, as the roll is unwound. The position of the contacting element is then sensed and used to determine the diameter of the roll **10**. Alternatively, the diameter sensor **170** may be fixed and may utilize a non-contacting means to determine the position of the edge of the roll **10**. Non-limiting examples of the diameter sensing means include ultrasonic pulses, non-coherent electromagnetic beams or pulses, or laser beams or pulses. A Hyde Park SUPERPROX SM556A-400LE available from Hyde Park Electronics Inc., Dayton, Ohio, is an exemplary sensor for determining the roll **10** diameter.

The apparatus may comprise a rotation sensor **175** to determine the speed of rotation of the roll **10**. The speed of rotation of the roll **10** may be determined by means of a speed resolver, tachometer, or other means as are known in the art. An exemplary sensor for determining roll rotation speed is an Allen Bradley 845H encoder available from Rockwell Automation, Milwaukee, Wisconsin.

The apparatus and method of the present invention may be used to unwind any type of web material **11** from any size roll **10**. The method is particularly useful for unwinding large rolls **10** of high bulk, low density (<10 g/cm^3) tissue paper. Rolls are wound about a longitudinal axis. The roll **10** may be wound around a core **13**, coincident with the longitudinal axis, or may be coreless.

Rolls **10** are generally wound with the axis of the roll **10** horizontal, (parallel to the plane of the horizon). The winding axes of the rolls **10** unwound by the method of the invention are vertically oriented. This axis orientation can be accomplished by upending equipment or other means as is known in the art. Upending refers to the reorientation of a roll **10** of material from a position wherein the longitudinal axis of the roll **10** is horizontal to a position wherein the longitudinal axis is substantially vertical.

The dimensions of the roll **10** are not critical to the practice of the invention. The apparatus and method may be used to unwind rolls **10** having widths and diameters of only a few centimeters. Alternatively, the method and apparatus may be used to unwind rolls **10** having dimensions of several meters. The method and apparatus of the invention are particularly useful for the unwinding of rolls **10** of web material having a width and diameter of about 250 centimeters. Applicants believe that the method and apparatus of the invention may unwind rolls of any diameter that may be manufactured.

The apparatus comprises at least one drive element **100** adapted to contact and rotate the roll **10** of web material **11**. The drive element **100** may contact any surface of the roll **10**. The drive element **100** may contact at least a portion of: the lower surface of the roll **10**, the upper surface of the roll **10**, the circumferential surface of the roll **10**, or the inner surface of the core **13** of the roll **10**. Embodiments where multiple drive elements **100** are used and contact at least portions of multiple surfaces of the roll **10** are also possible.

Vertically oriented rolls have a characteristic telescoping force, and a core slippage force. The telescoping force is the force that must be overcome to cause the windings of the roll **10** to slip past one another as the tubes of a multiple tube telescope slip past each other. The core slippage force is the force that must be overcome to cause the innermost windings of the roll **10** to slip relative to the core **13**. A roll **10** is considered telescoping if the force of gravity is sufficient to overcome the telescoping force of the roll **10**. Similarly, a roll **10** is considered non-telescoping if the force of gravity is not sufficient to overcome the telescoping force of the roll **10**. The lower surface of a telescoping roll **10** typically needs to be completely supported while the lower surface of a non-telescoping roll **10** does not need complete support.

The apparatus for non-telescoping rolls may comprise a core support element **120** as part of the drive element **100**. The core support element **120** may be expanded radially after being inserted into the roll core **13**. This expansion couples the mass of the roll **10** to the drive element **100**. The drive element **100** may then rotate the roll **10** by applying torque to the core support element **120**. The torque may be applied by any means known in the art. As non-limiting examples, the core support element **120** may be belt driven; chain driven; gear driven; or direct driven. The core support element **120** may extend completely through the roll core **13**, or alternatively, only a portion of the way through the core **13**.

In one embodiment the apparatus includes a stabilizing element **150** adapted to stabilize the upper end of the roll **10** that is vertically oriented. For unwinding rolls **10** wound on a core **13**, the stabilizing element **150** is adapted to engage the core **13** during unwinding and then to move out of the way when the core **13** is being removed and a subsequent roll **10** is being placed on the unwind station. As a non-limiting example, an overhead gantry system with the capability of moving the stabilizing element **150** in mutually orthogonal x-y and z directions may be utilized. Alternatively, the stabilizing element **150** may be capable of movement in only the z direction. In this embodiment the stabilizing element **150** moves down to engage and stabilize the core **13**. The stabilizing element **150** moves up to free the core **13** when removal of the core **13** is desired. The stabilizing element **150** may also be configured to move along a path from a disengaged position out of contact with the core **13** to an engaged position in contact with the core **13**. A pneumatic chuck, a rotating eccentric chuck, or any otherwise radially expanding device may be used to positively engage the core **13** of the roll **10**.

The stabilizing element **150** may be adapted to contact a portion of the upper surface of the roll **10**. The stabilizing element **150** may be used alone or in conjunction with an upper core stabilizer as described above. The stabilizing element **150** may also be powered and function as a drive element in addition to stabilizing the roll **10**.

Reorientation:

Figure 1 illustrates the apparatus for reorienting the plane of the web **11** from vertical to horizontal. As the web **11** unwinds and is routed toward a downstream process, it may be advantageous to reorient the web **11** from a vertical to a horizontal plane. This reorientation may be accomplished by routing the path of the web **11** around an angled web turning element **400**. The web **11** is then routed around a second web turning element **420** having a horizontal axis and the resultant plane of the web **11** will also be horizontal.

The first turning element **400** and second turning element **420** may be rolling elements capable of rotating with the web **11** as the web passes around the turning elements. Either, or both, of the turning elements **400, 420** may be driven elements capable of imparting power to the web **11**. As a non-limiting example, the rolling web turning elements **400, 420** may be comprised of carbon fiber spans, and hubs supported by rolling element bearings.

The rolling resistance of the turning elements **400, 420** should be minimized to reduce the drag forces on the moving web **11**. Excessive drag forces may damage or break the web **11**. The inertia of the turning elements **400, 420** should also be minimized to reduce the extent to which the turning elements continue to turn after the web **11** has stopped. The continued movement of the turning elements **400, 420** after the web **11** has stopped may also damage or break the web **11**.

The speed of driven turning elements **400, 420** should be controlled to impart no more drag force to the web **11** than the desired level. The speed should also be controlled as the web **11** starts and stops to reduce the relative motion between the web **11** and the turning elements **400, 420**.

The turning elements **400, 420** may be grooved rollers. Grooved rollers may be one way ascending – the grooves angled up in the direction of web travel. The grooved rollers may alternatively be one-way descending, the grooves angled down in the direction of web travel. Alternatively, the grooved rollers may be center grooved. Center grooved rollers have grooves on either side of the roller midpoint angled toward the midpoint.

Alternatively, the turning elements **400, 420** may be fixed with respect to the moving web **11**. The turning elements **400, 420** may comprise a plenum, an air supply **430**, and a plurality of orifices arranged on the periphery of the turning element **400, 420** in that portion of the periphery underlying the web **11**. When the air supply is activated, air flows through the plenum, out of the orifices and supports the web **11** as it moves past the turning elements **400, 420**. The air turning elements subject the web **11** to lower levels of drag forces than rolling turning elements do because the web **11** is traveling on a supporting cushion of air and the movement of the web **11** does not need to overcome the frictional resistance of a rolling turning element.

As the web **11** unwinds from the roll **10**, it is routed to downstream equipment. It may be necessary to orient the plane of the web **11** to horizontal as described above. It may also be necessary to support the web **11** as it travels from the unwind station to the downstream equipment. The span of the web between supports will vary depending upon the properties of the web being processed and the demands of the process itself

In one non-limiting embodiment, lightweight webs **11** must be supported in transit to prevent wrinkling, sagging, and edge curling of the web **11**. Supporting the web **11** such that no open span of the web **11** exceeds three times the width of the web **11** will reduce the occurrence of these undesirable conditions. That is, for a web **11** of width w, the spacing between supports should not exceed $3w$. More specifically, the spacing should not exceed $2w$. Still more specifically, the spacing should not exceed $1w$.

Wrinkling of the web **11**, where a portion of the web **11** folds onto the web **11** itself, can result in unacceptable product when the converting equipment downstream processes the wrinkled web **11**. Sagging between supports can lead to web **11** positioning errors and unacceptable product downstream. Edge curl, where the edges of the web **11** curl out of the web plane can be indicative of excess local web tension and can stretch the web **11** resulting in an unacceptable level of variation in the downstream product. In another embodiment processing stiffer webs, longer spans are possible.

The web **11** should be supported by lightweight rolling elements as described above to reduce the drag forces on the web **11**. In another embodiment, the web **11** may be supported on air-cushioned elements as described above to minimize web **11** contact surfaces.

Roll Transport:

Vertically oriented rolls may be transported to the unwind station on a transport element **180** shown in figure 2, or without a transport element **180**. Transporting the roll **10** on a transport element **180** reduces the possibility of damaging the roll **10** during transport since the transport equipment contacts the transport element **180** and not the roll **10** itself. The transport element **180** may be configured to support the entire lower surface of the roll **10** or a portion of the surface, or just the core **13** of the roll **10**.

The transport element **180** may be adapted to rotate with the roll **10**. In this embodiment the roll **10** may be at least partially driven by contact between the lower surface of the roll **10** and the rotating transport element **180**. This contact surface advantageously provides a large, relatively non-compressible surface for driving the roll's rotation. The lower surface of the roll **10** is coupled to the transport element **180** by gravity and the friction between the web **11** and the transport element surface. The transport element **180** may be rotated by any means known in the art. As non-limiting examples, the transport element **180** may be driven by friction rollers, it may be belt driven, chain driven, gear driven or directly driven. In each case the controller controls the speed of the transport element 180.

The roll **10** may also be driven by contacting the circumferential surface of the roll **10** with either drive belts, or a friction roller. Multiple drive elements **100** in combination may be used to rotate the roll **10** as well. The roll **10** may be driven by contact between drive elements **100** and at least portions of the lower surface, upper surface, inner surface of the roll core **13**, and the circumferential surface.

The apparatus may comprise a counterbalance element **190** illustrated in figure 2, adapted to offset at least a portion of the mass of the roll **10**. The counterbalance element **190** may be comprised of a lever and fulcrum; a jackscrew; or other elevating means as known in the art. The counterbalance element **190** may be used to alter the distribution of the weight of the roll **10** on the support structure. The counterbalance element **190** elevates the core **13** of the roll **10** such that the roll no longer contacts the table. For rolls having sufficient core slippage force levels, and sufficient telescoping force levels, the support of the roll **10** can be focused on the core support **120** rather than on the roll support table.

Focusing the support of the roll **10** on the core support **120** reduces the pressure applied to any roll layer that is folded under on the lower surface of the roll **10**. By offsetting the mass of the roll **10**, the pressure on the folded layers may be reduced such that the fold will unwind without tearing the web **11**.

Non-telescoping rolls may be transported and unwound on a transport element **180** having a stepped core support **120** or a convex upper surface **182**, such that the transport element **180** contacts only the core **13** of the roll **10**. The surface may be convex by as little as a few tenths of a millimeter, or as much as several centimeters (this amount being the difference in height measured from the edge of the element to the center of the transport element **180**). A convex transport element **180** reduces the incidence of web tears resulting from imperfect windings on rolls **10**. In some instances, the windings of rolls **10** are not completely parallel with one another. The edges of the windings may be folded over when the roll **10** is oriented vertically such that the inner windings rest on the folded portion. The weight of the inner windings can cause tearing in the web **11**, as it is unwound. The inner windings of a roll **10** supported only by its core **13** and placed on a convex surface exert little if any weight on the folded windings and the folded layers may be unwound without tearing.

The transport element **180** may be adapted to support the roll **10** with a cushion of air. The transport element **180** may have an air plenum and a plurality of orifices **184** on the roll contacting surface. Air may be introduced into the air plenum through a rotary union coupled to the axis of rotation of the transport element **180**. As the air exits the plurality of orifices **184**, the roll **10** is lifted and supported on a cushion of escaping air. The air cushion allows folded portions of outer layers to freely unwind without tearing due to forces exerted by the inner layers.

The air plenum of the transport element **180** may be multi-chambered. The air supply may further comprise a manifold having discrete supply lines for each chamber and control valves in each supply line. As the roll **10** unwinds the orifices of the outer chambers will be uncovered. The air supply to the outer chambers may be reduced or completely turned off to reduce the amount of compressed air consumed.

The roll **10** may be rotated while the transport element **180** remains stationary. When reducing the speed of rotation of the roll **10**, or stopping the rotation completely is desired, the air cushion may be removed by shutting off the air supply. This allows the roll **10** to settle on the surface and forces contact between the roll end surface and the surface of the element resulting in a braking force being exerted on the roll **10**.

Method of unwinding:

In one embodiment, the method includes the step of maintaining the tension in the web **11** at a desired tension. The desired tension is determined according to the physical properties of the web material. The desired tension for a tissue paper web **11** may be about 2 Newtons per lineal centimeter of web width. More specifically, the web tension may be maintained at less than 0.5 Newtons per lineal centimeter of web width, as the web **11** is unwound. Low web tensions (<2 N/cm) reduce the occurrence of web breakage when unwinding low-density tissue papers. These papers may be unwound at very low tensions (<0.5N/cm) to reduce the occurrence of wrinkling and edge curl in the web **11**, as it is unwound.

The desired tension may be input to a controller by a process operator by means of a computerized operator interface, or alternatively, by means of a potentiometer, thumbwheel switch, or other input means as are known in the art. The actual tension may be monitored by wrapping the vertically oriented web **11** around a vertical roller adapted to facilitate the measurement of web tension. The roller has load cells incorporated into the roller end supports. Comptrol Tensioncell loadcells, model numbers BB30P12k, and BB30N12K available from Comptrol Inc., Cleveland, Ohio, are exemplary load cells suited to this purpose. The force on the roller due to web tension may be sensed and web tension calculated by a controller from the force and the geometry of the web wrap around the roller. The controller then compares the actual and desired web tensions determining the difference between the two as the web tension error. The controller may then adjust the speed of the web **11** to reduce the web tension error to zero.

The speed of the web **11** may be adjusted by adjusting the rotational speed of the drive element **100** or drive elements. Alternatively, the speed of the web **11** may be adjusted by adjusting the speed of an s-wrap drive element. An s-wrap drive element, illustrated in FIG 4, comprises two vertically oriented rollers. At least one of the rollers is a powered roller. The web **11** is routed around the pair of rollers such that the rotation of the powered roller is imparted to the web **11** through the contact between the web and the roller. Adjusting the speed of the roller then adjusts the speed of the web.

The speed of the web **11** may be controlled to maintain a predetermined web speed. Controlling the speed of the web **11** comprises determining a desired speed of the web **11**; determining the actual speed of the web **11**; determining the difference between the desired and actual speeds as the web speed error; and adjusting the speed of the web **11** to reduce the web speed error to zero. Under normal operating conditions, the web speed may be maintained at a predetermined speed within acceptable control limits. A web speed of about 200 meters/minute may be maintained. More specifically, a web speed of 750 meters/minute may be maintained. Still more specifically, a web speed of 1000 meters/minute may be maintained. Web speeds in excess of 1600 meters/minute may be maintained depending upon the performance capabilities of the downstream equipment.

Web speed is a function of the rotational speed of the roll **10**, and the circumference of the roll **10**. Since the roll **10** circumference diminishes as the roll **10** unwinds, the rotational speed of the roll **10** must increase to maintain a constant web speed. The rotational speed increase may be made in discrete steps or may be continuously increased. Increasing the speed in steps will result in greater variation in the speed and tension of the web **11** since the speed changes will be discrete while the change in the circumference will be continuous.

Web speed is calculated using the speed of rotation of the roll **10** and the diameter of the roll **10** as inputs. In one embodiment the diameter is measured using a sensor as described above. The distance from the sensor to the edge of the roll **10** is measured, and the diameter is calculated. To reduce the affects of variations in the roll diameter, a rolling average of the distance measurement may be used for the calculation rather than a discrete measurement value. A rolling average is the average value of a set of time stamped measurement values. The average is considered rolling in that the oldest value in the set is dropped when a new value is added. The average is therefore always of the same number of values and always of the most recent values. The speed of rotation is measured as described above and the speed is then calculated as a function of the diameter of the roll **10** and the speed of rotation of the roll **10**.

In another embodiment, the initial roll diameter is determined and input into the controller. The controller then calculates the change in the roll diameter using the ratio of the angular displacement of the unwind station to the angular displacement of a known diameter downstream roller. The speed of the web **11** is then calculated as a function of the calculated diameter of the roll **10** and the speed of rotation of the roll **10**.

As noted above, the tension of the web **11** is in part a function of the speed differential between the unwind station and the downstream equipment. The tension may be controlled by rotating the unwind station at a progressively higher rate as the roll **10** unwinds to maintain a constant web speed, and varying the speed of the downstream equipment to maintain the proper level of web tension. Alternatively, the downstream equipment speed may be maintained at a constant desired level and the rotation of the roll **10** may be varied to maintain the desired speed and tension in the web **11**. In another alternative the tension of the web **11** may be controlled using s-wrap rollers as described above.

The web **11** may also be unwound according to a desired web speed without regard to web tension. In this embodiment, the desired web speed is entered into the controller and the rotation of the roll **10** is controlled to achieve and maintain the desired speed. The desired speed may be a fixed value or may be derived according to the speed of the downstream equipment.

The rotation of the roll **10** may be continuous from its inception until the roll **10** is completely unwound. The rotation may be performed in an intermittent fashion, stopping and starting as the need of the downstream processes dictates. The terms continuous and intermittent refer to the intent regarding the unwinding of the web **11**. Continuously unwinding therefore refers to an intent to unwind the web **11** from inception to completion, and intermittent refers to an intent to unwind the web **11** in predetermined sections, stopping the unwinding between sections. In both continuous and intermittent unwinding, the method allows for the cessation of the rotation in the event of a web **11** break during the unwinding process.

Splicing:

The unwinding apparatus of the present invention facilitates the splicing of one roll **10** to another. Splicing is defined as attaching the web **21** of a subsequent roll **20** to the web **11** of a previous roll **10** such that the web of the first and second rolls may be routed to the downstream equipment without a break in the web **11**. Splicing may be performed while the webs are in motion (a flying splice) or while the webs are stopped.

Splicing rolls without stopping the process reduces the need to ramp down and ramp back up the speed of the process, and yields greater converting productivity. More time is utilized converting rolls to end products and less time is spent starting and stopping the process.

Figures 3a – 3d illustrate one embodiment of an apparatus for splicing multiple rolls **10** of web material **11**. In this embodiment, an operator prepares the second roll **20** by unwinding one or more layers of web **11** and cutting the leading edge in the shape of a "V", or the web **11** may be cut perpendicular to the machine direction. Perforated double-sided splicing tape is then applied to the second web **21**. When a predetermined amount of web **11** remains on the first roll **10**, the first roll **10** is translated to a new position upstream of the original unwind position. The second roll **20** is placed in the position vacated by the first roll **10**. The second roll **20** is accelerated such that the speed of the web **21** at the outer circumference of the second roll **20** matches the unwinding speed of the first web **11**. A pivoting splice roll **300** moves the first web **11** into contact with the rotating second roll **20**. When the splicing tape on the leading edge of the second web **21**, contacts the first web **11**, the two webs become attached to each other and the second web **21** begins to unwind. The first web **11** is then either cut with a cutoff bar (not shown) or broken by slowing the rotation of the first roll **10**. In one non-limiting embodiment, the web is broken by a combination of using a cutoff bar and braking the rotation of the first roll **10**. The double-sided splicing tape may alternatively be placed on the second web **21** at a point distant from the leading edge of the web **21**.

In another embodiment, the first web **11** may be accumulated in a festoon system as is known in the art by unwinding the first web **11** at a web speed greater than the speed of the downstream process. When a sufficient amount of the first web **11** is accumulated in the festoon, the first roll **10** may be stopped, the first and second webs joined as described above, the remainder of the first web **11** separated from the joined webs, and the second roll **20** rotated to unwind the second web **21**.

Alternatively, the web **11** may be spliced by preparing the second web **21** for splicing as described above, then stopping the first roll **10**, joining the first and second webs as described above, separating the first web **11**, and starting the rotation of the second roll **20**.

Multiple plies:

The apparatus of the present invention may be adapted to facilitate the concurrent unwinding of multiple webs. These multiple webs may then be converted into multi-ply paper products having at least two plies. For each ply desired in a finished product, two unwind stations and splicing apparatus are provided to allow for flying splices as the converting process proceeds. The apparatus for each ply may also comprise a force measuring support roll, web supports as necessary, an angled element, and subsequent horizontal element, to orient the web **11** of each ply to a horizontal plane. The apparatus for the multiple plies may be disposed side by side at a single elevation, or the apparatus may be disposed at multiple elevations. Multiple elevation apparatus may be stacked one above another to facilitate the converting process and/or to reduce the overall floor space requirements.

A single controller may be used to monitor the tension in multiple webs and to adjust the rotation of the multiple rolls **10** accordingly. Alternatively, individual controllers may be used for the rolls of each ply.

The orientation of the "wire side" of the paper plies in the finished product may be controlled by the geometry of the turning elements. The wire side of each ply will have the same orientation as the webs unwind. Each web **11** is reoriented by routing the web **11** from vertical with the direction of movement parallel to the floor; to vertical with the direction of movement perpendicular to the floor; to horizontal with the direction of movement parallel to the floor. Routing one web **11** perpendicular to, and moving toward, the floor and the other web **11** perpendicular to, and moving away from, the floor, the wire side of each web **11** may be configured as the outer surface of a two ply product. In another embodiment, the wire sides may be configured as the inner surfaces of a two-ply product. In another embodiment, the wire side of a first ply could be configured in a face-to-face relationship with the fabric side of a second ply.

What is claimed is:

1. An apparatus for unwinding a vertically oriented roll of web material, the roll comprising a lower surface, an upper surface and a circumferential surface, characterized by comprising:
   a) at least one drive element adapted to rotate the vertically oriented roll;
   b) a sensor adapted to measure a tension of the web;
   c) a controller adapted to adjust a speed of the web according to the tension of the web.

2. The apparatus according to claim 1, comprising:
   d) a first turning element adapted to reorient the web from an orientation wherein the web lies in a vertical plane and has a motion vector parallel to the horizon, to a subsequent orientation wherein the web lies in a vertical plane and has a motion vector perpendicular to the horizon;
   e) a second turning element adapted to orient the web from the subsequent orientation, to a second subsequent orientation wherein the web lies in a horizontal plane with a motion vector parallel to the horizon.

3. The apparatus according to claim 1, comprising a table adapted to support the roll on the lower end surface of the roll.

4. The apparatus according to claim 3, wherein the table comprises an upper surface comprising a plurality of orifices; the apparatus comprising:
a compressed air source adapted to apply compressed air to the lower end surface of the roll through the orifices of the table.

5. The apparatus according to claim 3, comprising a vacuum source adapted to apply a vacuum to the lower end surface of the roll through the orifices of the table.

6. The apparatus according to claim 3, wherein the table is adapted to support the roll as the roll is transported.

7. The apparatus according to claim 3, wherein the table is adapted to rotate with the roll as the web is unwound.

8. An apparatus for unwinding a plurality of rolls of web material characterized by comprising:
   a) a first drive element adapted to rotate a first vertically oriented roll;
   b) a first sensor adapted to measure the tension of the first web;
   c) a first controller adapted to adjust the speed of the first web according to the tension of the first web;

d) a second sensor adapted to measure the speed of the first web;

e) a second drive element adapted to rotate a second vertically oriented roll;

f) a second controller adapted to adjust the speed of the second web according to the speed of the first web;

g) a splicing element adapted to move the first web into contact with the second web.

9. An apparatus for unwinding a roll of web material characterized by comprising:

a) at least one drive element adapted to rotate a vertically oriented roll;

b) a sensor adapted to detect a speed of the web;

c) a first controller adapted to adjust a speed of the web according to a desired speed of the web.

10. The apparatus according to claim 9, comprising:

d) a sensor adapted to measure a tension of the web;

e) a second controller adapted to adjust the speed of the web according to the tension of the web.

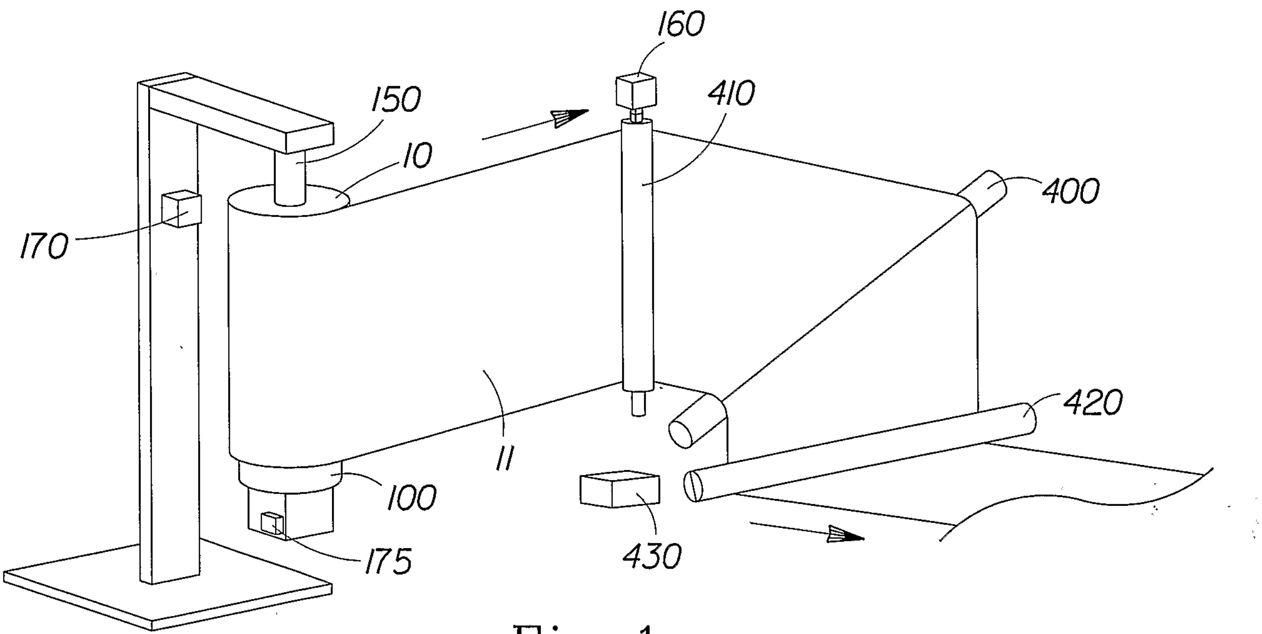

Fig. 1

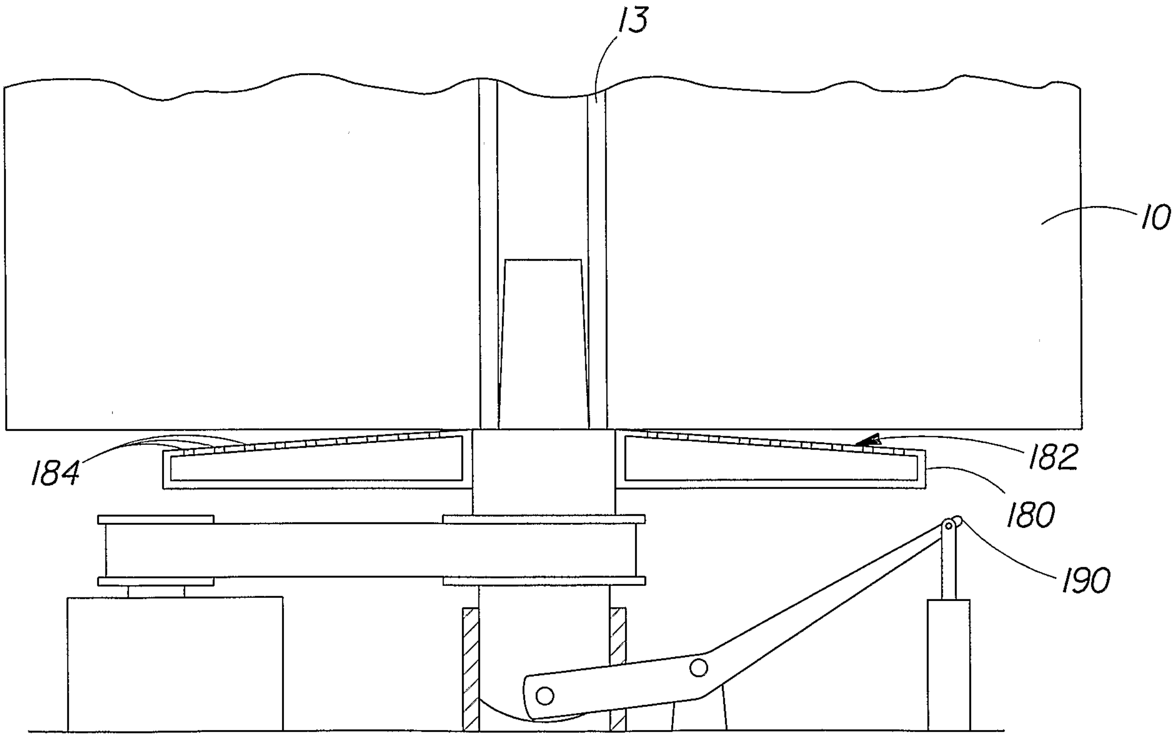

Fig. 2

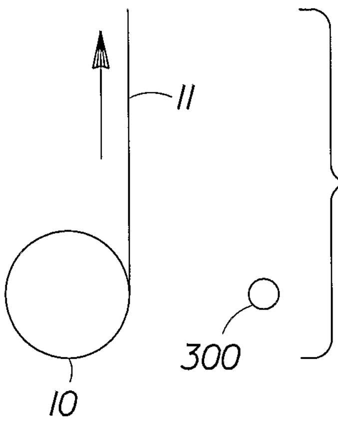

Fig. 3a

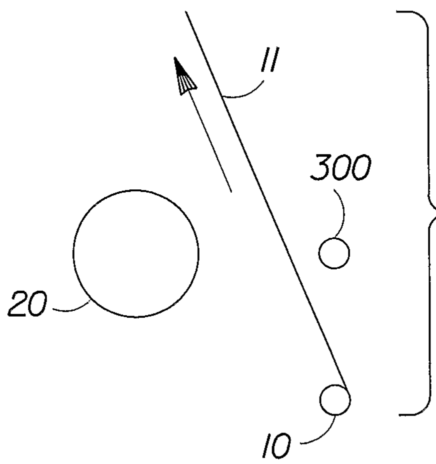

Fig. 3b

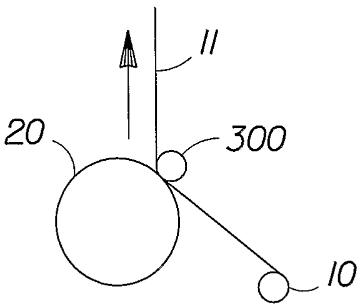

Fig. 3c

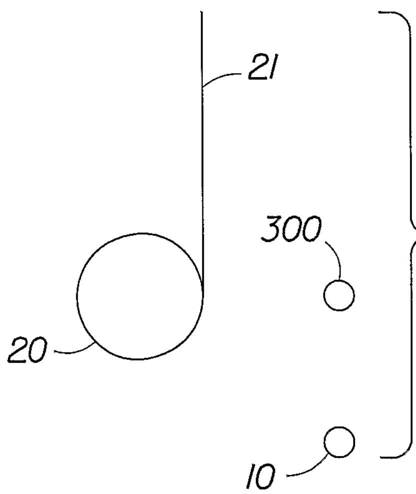

Fig. 3d

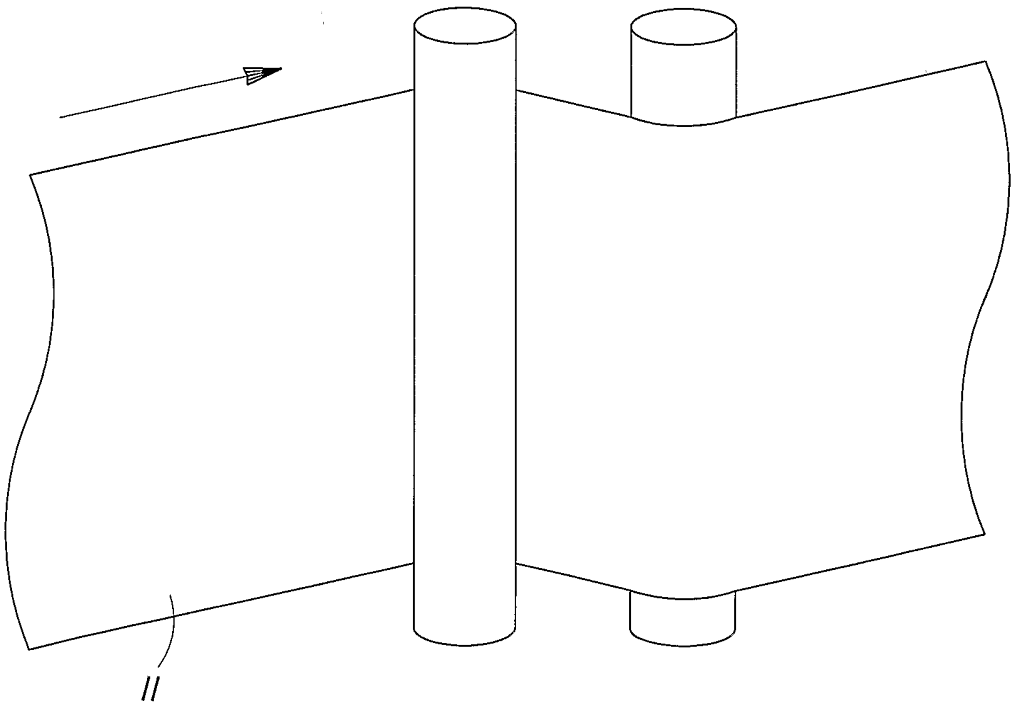

Fig. 4