CONTROL OF WEB DISTURBANCES ON FOURDRINIER MACHINES

FIG. 1

FIG. 2

FIG. 3

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This invention relates generally to papermaking on Fourdrinier machines, and more specifically to apparatus and methods for preventing non-uniform mechanical disturbances of the partially-formed web which take place in the table roll section of the machine.

On conventional Fourdrinier papermaking machines, the paper web is formed on the upper reach of an endless foraminous drainage support, which is supported by a breast roll at the wet end of the couch roll at the dry end of the machine. Normally, paper pulp stock is introduced on the foraminous drainage support commonly called the Fourdrinier wire, from a headbox which is positioned above the breast roll. The stock is drained of its suspending fluid as it progresses from the wet end of the machine to the dry end of the machine, and is finally compacted by the application of high vacuum before it leaves the Fourdrinier wire.

On conventional Fourdrinier machines, the foraminous support is moved over a series of table rolls located between the breast and couch rolls. Table rolls maintain the foraminous support substantially level to permit formation of a paper web during the passage of the foraminous support over the table rolls from the wet end of the machine where the stock is introduced to the dry end of the machine where the web is removed. In addition to supporting the Fourdrinier wire and maintaining it level, the table rolls are known to aid in the removal of liquid from the web. As the paper leaves the table roll, a substantial amount of suction is created in the nip between the Fourdrinier wire and the table roll as a space is opened up immediately following the nip. At least some of this space is filled by liquid drawn through the wire from the web. The amount of suction created in this outgoing nip is related to the kinetic energy of the stock on the wire, and consequently increases with the square of the machine speed. Approximately 70% of the suspending liquid is removed from the web by these table rolls before it reaches the suction boxes at the dry end of the conventional Fourdrinier machine.

Various defects have appeared in paper webs produced on conventional Fourdrinier machines which take the form of streaks and ridges. Ridges sometimes occur on the circumference of a tightly wound roll of paper that cannot be noticed by a visual inspection of an unmagified sheet. Such closely spaced streaks can show up in color reproduction where a large area is to be given a uniform color, as for example, in the background of a magazine illustration. These streaks are usually about 1/4" apart and extend for various lengths in the machine direction of the web.

A distinction should be made at this point between the above mentioned streaks or ridges, and the effect known as “two-sidedness,” which is a general difference in the quality of the two sides of the paper web caused by the more or less uniform washout of filler and tiny fibers on the wire side. This effect generally results in a general difference in light reflectance and finish of the two sides of the web. Machine direction streaks and ridges are believed to be the result of excessive localized washout of filler and tiny fibers on the wire side.

Stock, as it is introduced from the headbox onto the Fourdrinier wire is usually of fairly uniform consistency and fairly free from fiber flocculations. The main problem after introduction of the stock on the wire is to remove the liquid and form the sheet without permitting disturbances to impair the sheet formation. The tendency of fibers to flocculate again during drainage is the most serious deterrent to good web formation.

Sheet formation and fiber distribution deteriorate rapidly as the web speed is increased. Since the amount of fiber flocculation is inversely proportional to the drainage time, it would seem to follow that web formation and fiber distribution should be improved at high speeds, since the time available for flocculation decreases. This apparently logical theory does not hold true, however, probably because the higher speed greatly exaggerates non-uniform mechanical disturbances occurring in the table roll section of the machine.

Non-uniform mechanical disturbances occurring in the table roll section of the machine can cause poor drainage conditions. It is believed that the resulting non-uniformity in fiber distribution and moisture content shows up physically as streaks and ridges in the web.

Suction forces exerted on the web by the conventional table rolls result in a peculiar pattern of drainage at the outgoing nip of the roll. Uniformly spaced water curtains perpendicular to the roll and wire are formed on a single conventional table roll, the size and pattern of which are determined by the combination of roll diameter, wire speed, surface tension, etc. However, with multiple rolls, the configuration of these water or “drainage” curtains may also be affected by non-uniform entering nip conditions, and the curtains will generally form with non-uniform spacing among the streams forming them. The drainage curtains obtain their water from adjacent portions of the roll and wire. Hence, adjacent curtains compete for water. The energy needed in destroying a large curtain would be greater than in destroying a small curtain. Therefore, the large curtains have a competitive advantage and tend to grow at the expense of the smaller curtains.

Where there is slightly more water at a given position on the table roll or Fourdrinier wire, a large, stable curtain will form. This type of curtain tends to leave a trail of an excessive amount of water on the underside of the wire, which in turn triggers the formation of another large, substantially stable curtain at the same transverse position on the succeeding table roll. The trail left on the Fourdrinier wire by this second curtain triggers a third large curtain, and so on down the length of the machine.

It is a well established fact that a high positive pressure exists in the ingoing nip of a table roll. It is believed that when this pressure exerts its force on the streaks of excess liquid on the bottom of the Fourdrinier wire, the excess liquid is consequently forced back into the web at this point, resulting in a severe washout of smaller pulp fibers called "fines," an opening up of the interstices between the fibers of the web and, of course, excess moisture in this area of the web, this localized effect being much more severe than the general effect of two-sidedness. Also, the fibers disruption occurs again in the areas of the web where excess liquid is forced back into it. When this action occurs over a number of successive rolls at the same transverse location, the effect of the disturbance is augmented and can result in poorly formed, streaked paper generally resulting from mechanical disturbances in the table roll section of the machine.

The present invention provides a means for controlling the formation of the drainage curtains that occur at the outgoing nip of table rolls which are believed to cause non-uniform fiber disruption and moisture streaks resulting from mechanical disturbances in the table roll section of the machine.
The present invention also provides means for continuously and progressively shifting the position of the drainage curtains so that the pattern of curtains on successive rolls will not occur at the same transverse position.

According to the present invention, definite boundaries are provided in the surface of the table rolls to separate adjacent drainage curtains. The boundaries may best be provided by one or more relatively narrow and shallow indentations which extend in a spiraling manner around the table roll from end to end. The preferred type of indentation is a helical groove having a pitch of approximately one-half to three inches, depending on the location of the roll relative to the wet end of the machine. It is evident that the surface area of such a roll in contact with the Fourdrinier wire at any given instant will consist of a number of equal surface area portions, defined by the boundaries formed by the grooves. The groove or grooves in the surface of the table-roller which are directly under the Fourdrinier wire at a given instantaneous position as a boundary between adjacent curtains because there is no suction created directly above the groove due to the absence of a nip.

The word "indentation" is defined in this specification and in the claims as a broad term, meaning a series of notches, cavities, or a continuous groove. The present invention is not limited to a continuous groove, because a series of notches arranged in a spiraling manner around the surface of a table roll having a slight interruption may be substituted for the continuous groove and still perform the desired function. However, the term "groove" will be used hereafter in this specification because it presents the invention in its desired form.

The grooves or grooves in the surface of the table rolls are made of a very small width so that the total surface area of the roll occupied by the groove will be relatively negligible compared to the total surface area of the table roll. In this way, the suction inducing area of the table roll will not be impeded. Actually, the depth of the groove is not a critical feature, as long as it is deep enough to prevent a nip action from occurring at that point.

The grooves or grooves may be used in any table roll but preferably, according to this invention, the table rolls on the last two-thirds of the Fourdrinier wire on the dry end of the machine away from the headbox utilize the groove arrangement of this invention to give the most effective water curtain control.

The grooves or grooves in the surface of the roll are preferably made helical so as to continuously and progressively shift the water curtains in a transverse direction relative to the direction of travel of the web. Preferably, helical grooves in successive table rolls are made to the opposite hand, so as to shift the movement of the water curtains to oppose direction as the web passes over successive table rolls, completely eliminating any disturbance buildup in a single transverse position. This is not essential, however. One or more plain rolls may be positioned between grooved rolls, since successive plain table rolls inherit a curtain formation similar to the pattern of the preceding roll.

It has been found that helically grooved table rolls have a tendency to produce longer drainage curtains than non-grooved rolls. The curtains which form in the outgoing nip extend between the underside of the wire and the surface of the table roll in approximately perpendicular relation thereto. The curtains leave the roll with a mean velocity vector at an angle with the plane of the wire traveling at the table roll. This mean velocity vector of the drainage curtains leaving grooved table rolls is at a smaller angle to the wire than the velocity of the drainage curtains leaving comparable non-grooved table rolls, and the drainage curtains have sufficient momentum to overcome its surface tension, eventually breaking the curtains into arrays of small water droplets. This does not increase the quality of drainage, however. This altered velocity vector aids the removal of water by centrifugal force, leaving the lower and rear surfaces of the roll relatively dry. However, since the water leaves the roll with a roll with a higher transverse velocity component, the curtain may translate into the succeeding table roll where one or more of it may adhere to the roll's surface and be forced back into the web. Thus, a disturbance is caused at the ingoing nip of the roll. To remedy this situation, it may be desirable to install a plate or deflector on the downstream side of each grooved table roll in a position so as to deflect the drainage curtains in a downward direction. The quantity of liquid removed from the web may be increased as much as 40% by using deflectors when the grooved rolls are spaced close together, as contrasted with using no deflectors.

As hereinbefore stated, the pitch of the grooves in the roll should depend on the relative location of the particular roll to the wet end of the machine. Table rolls with closely spaced grooves, providing very small land areas which induce very little drainage, are sometimes placed adjacent the headbox for the purpose of retarding drainage for a predetermined distance. This type of grooved roll is well known in the papermaking art, and is used extensively on present papermaking machines. However, at the point where it is desired to begin drainage by table roll induced suction, whether it is adjacent the breast roll or downstream from the above mentioned drainage retarding rolls, the groove arrangement according to this invention are preferably grooved with a pitch and placed on the machine according to the expected consistency of the web at a given position. Near the wet end of the machine, the pitch of the grove is made relatively small, say ½" to 1", so that there will be a relatively large number of grooves in the roll to reduce stock jump but at the same time, have a sizeable plane area to facilitate drainage, and nearer the dry end of the machine, the pitch is made relatively large to 3", so that this will be a relatively large drainage inducing area on the roll. The width of the grooves is made relatively small, say ¾", so as not to impair the drainage inducing capacity of the roll, and the depth is made about 1/32", which is just enough to prevent a nip from forming at this location. Comparing the foregoing measurements in relation to each other, the ratio of the surface width between the helices of the grooves or indentations to the width of the grooves or indentations should be at least 4:1 (¾:"1"), and should increase to a higher ratio nearer the dry end of the machine up to 24:1 (3":16").

In the past, several different specifications have led to the use of grooved table rolls on papermaking machines. For the Fourdrinier wire on the dry end of the machine, the grooves were designed in different ways. In the prior art, such as the patent to Johnstone, #1,957,963, substantially wider and more shallow cavities are provided in the surface of the table rolls to induce a capillary attraction, drawing drainage into the cavities of the roll's surface as the web passes over, and expelling the water by centrifugal force. Also in the past, an attempt has been made to completely eliminate the two-sidedness of paper webs by providing table rolls with very closely spaced grooves of sufficient depth or capacity to accommodate the drainage which normally would be forced back into the web at the ingoing nip of the table roll, thereby reducing the washout of lines and filler. However, the present belief is that the drainage inducing capacity of these types of rolls would be seriously impaired because only the very narrow land areas have the ability to produce suction in the outgoing nip. In the present invention, no water is expelled from the grooves in the roll to wash out lines, but in the contrary, the grooves divide the surface area of the roll into a number of drainage inducing land areas between adjacent grooves where substantially all the drainage is taken place, indicating that no drainage occurs over the grooves. Actually, mathematical and experimental conclusions indicate that a positive pressure occurs between the groove and wire, which is proportional to the wire speed.
In the drawings:
FIGURE 1 is a schematic side elevation of a conventional Fourdrinier machine.
FIGURE 2 illustrates the non-uniform configuration of drainage curtains on two successive plain rolls.
FIGURE 3 illustrates the uniform configurations of drainage curtains on two successive grooved rolls.
FIGURE 4 is a top view of a preferred arrangement of a series of grooved table rolls in the present invention.
FIGURE 5 is a top view of another embodiment of the invention showing an arrangement of grooved and non-grooved rolls.
FIGURE 6 is a top view of still another embodiment of the invention showing an arrangement of grooved and non-grooved rolls.

FIGURE 7 is an enlarged partial view of a grooved table roll.

Referring to FIGURE 1, liquid pulp stock 10 from a conventional stock headbox 12 at the wet or infeed end of the machine is introduced onto a Fourdrinier wire 14, the rate of stock flow from the headbox 12 being controlled in conventional fashion by using an adjustable gate (not shown) normally positioned at the outlet 16 of the headbox 12. The Fourdrinier wire 14 comprises the usual endless wire mesh conveyor which is mounted for continuous movement at a uniform rate of speed by conventional means. The solid roll 18 at the wet or infeed end of the machine and a couch roll 20 at the dry or discharge end of the machine where the paper web 22 is removed from the machine and handled in the customary manner by the usual pressing, drying and calender rolls (not shown). In conventional Fourdrinier machines, the wire 14 is supported between the couch roll 20 and the solid roll 18 by a series of table rolls 24. In the present invention, all or a portion of these table rolls are grooved in a manner as illustrated in FIGURES 4, 5 and 6.

Although not shown in the drawings, a so-called wire pit, which is simply an open liquid collecting sump, is positioned below the entire conveyer assembly extending from the wet end to the dry end of the machine. In conventional practice, liquid from such a sump is continuously mixed with fresh measured amounts of pulp and recharged to the headbox 12 in a well-known manner.

FIGURE 2 illustrates one of an infinite number of possible drainage curtain patterns on successive ungrooved table rolls. As the wire 14 moves over successive ungrooved table rolls 24, drainage curtains 50, 52 and 54 form at the outgoing nip of table rolls 24. The curtains are retained. This sketch illustrates the fact that table rolls inherit a curtain pattern very similar to the preceding roll. Also, residual liquid on the roll and the underside of the wire is shown. The curtains usually grow and decay to a large extent, but a very definite curtain alignment can be noticed on successive rolls. Note especially the large residual of liquid on the roll and wire left by the larger curtain 54. Small curtain 52 and medium-sized curtain 50 also leave a residual of liquid on the wire and roll, although not as pronounced as the residual left by large curtain 54.

FIGURE 3 illustrates the effect of grooved rolls on curtain formation. It can readily be seen that the curtains 55 form in the mid-portion of the land areas between grooves. Hence, the curtains 55 are of uniform size and spacing. Table roll 30 has right hand grooves, and as the roll rotates, the curtains will progressively move from left to right as viewed. Table roll 32 is left hand grooved, and as the roll rotates, the curtains will progressively move from right to left as viewed.

Although not shown in this drawing, a baffle plate could be positioned between roll 30 and roll 32. If the rolls are sufficiently close that curtains are carried into the going nip of the succeeding roll. This baffle plate would be substantially perpendicular to the wire extending from just under the wire downward for a length of approximately equal to the diameter of the rolls. This baffle plate would act as a deflector for the drainage curtains and prevent them from contacting the next roll. For simplicity, the spray resulting from the curtain breaking up, is not shown in the drawing.

The preferred form of the present invention as shown in FIGURE 4 comprises a series of helically grooved table rolls 30 and 32, replacing the old, plain surface table rolls. In most instances, the ideal table roll arrangement is to have each roll grooved, and have successive rolls grooved to the opposite hand. As shown in FIGURE 4, table rolls 30 have a right hand helical groove and table rolls 32 have a left hand helical groove. A deflector or baffle plate 36 is positioned between adjacent rolls as shown. The rolls bear upon the baffle plate members 38 and are rotatably mounted therein.

Other table roll arrangements are illustrated in FIGURES 5 and 6. Positioning of the grooved rolls will depend somewhat on wire speed and stock consistency. In some instances, curtains may be satisfactorily controlled by the arrangements as shown in FIGURES 5 and 6. In FIGURE 5, grooved rolls 30 and 32 are alternated with plain rolls 34, and successive grooved rolls 30 and 32 are grooved to the opposite hand. The plain rolls 34 tend to inherit a curtain pattern similar to the preceding grooved roll, 30 or 32, although the curtains are not as well defined. In FIGURE 6, the table rolls 30 at the wet end of the machine are grooved, and the table rolls 30 and 34 at the dry end of the machine are alternately grooved and plain.

In the roll arrangements shown in FIGURES 5 and 6, the possibility of curtains occurring at the same transverse location on successive rolls increases, but creates no definite improvement in the control of the curtains can be noticed over plain rolls.

In FIGURES 4, 5 and 6, a baffle plate or deflector 36 is mounted a short distance downstream from each grooved roll, and may be mounted downstream from the plain rolls, also. The distance between the baffle plate or deflector 36 and the nearest portion of the roll should not be less than about ¾". Also, the baffle plate or deflector 36 should not be mounted so high as to touch the underside of the Fourdrinier wire.

FIGURE 7 is an enlarged partial view of a grooved table roll. The surface of the rolls are divided into a relatively large suction inducing area 40, and the groove or grooves 42 which occupy a relatively negligible suction area compared to the suction inducing portion 40. Normally, the table rolls have an outer portion constructed of rubber or some similar material, and a metal shaft 44 on which the roll rotates. The groove or grooves 42 are preferably about ¼" to ⅛" deep and about ⅛" to ⅜" wide. Hence, for a ⅛" pitch groove, the area of the roll occupied by the groove is relatively small compared to the total surface area of the roll.

Due to the decreasing amount of liquid contained in the web, and consequently to be removed from the web as it progresses from the wet end of the machine to the dry end of the machine, the grooves in the table rolls adjacent the breast roll should be spaced closer together than the grooves in the table rolls adjacent the couch roll to prevent the formation of excessively large drainage curtains on the table rolls at the wet end of the machine.

In addition to the previous functions of table rolls, the present invention provides them with a new function, that of controlling the drainage curtains that form in the outgoing nip of the roll. The ability of these grooved table rolls to perform this function depends primarily on the wire speed, groove pitch and headbox consistency.

In order for the grooved rolls to function to the best of their ability, proper relationship between these variables needs to be established. The relationship of these variables to curtain control is as follows:

1. Generally, a groove pitch of approximately 1 inch is most effective. A groove pitch of approximately 1½ inch...
is also quite effective, but the effectiveness of pitch is altered by wire speeds and stock consistencies. For example, the result of using a 1” groove pitch in combination with high stock consistencies is very much better than at low stock consistencies. However, the 1” groove pitch proves more effective at low wire speeds than at high wire speeds.

(2) The use of higher stock consistencies generally results in better curtain control, but the effect is profoundly altered by wire speed and groove pitch. At low wire speeds, increasing the stock consistency results in a sizeable improvement in curtain control. At 1” pitch, the effect of consistency is moderate and depends on wire speeds. At high wire speeds, increasing the consistency results in less curtain control. At 1½” pitch, the higher consistency generally results in better curtain control, but at high wire speeds, the effect is negligible.

The relative slice jet velocity of the headbox and the wire speed also influence the drainage efficiency, and their precise effects are interconnected. Depending on the relative jet velocity, a change in wire speed can either increase or decrease drainage efficiency. The following relations are found to hold true:

(A) At high wire speeds, the drainage efficiency decreases when the relative jet velocity increases.

(B) At low wire speeds, the drainage efficiency increases when the relative jet velocity increases.

(C) At high jet velocity, the drainage efficiency decreases as wire speeds increase.

(D) At low jet velocity, the drainage efficiency increases as wire speeds increase.

(E) The overall drainage efficiency of the grooved roll is slightly less than that of a plain, ungrooved roll.

As may be concluded from the above, detail features of the invention such as positioning of grooved rolls, groove pitch, etc. may best be designed according to existing operating conditions. However, for the most part, headbox consistency, slice jet velocity, wire speeds, and relative roll speeds do not change very often on a paper machine, and the rolls may be designed to meet the more or less standard operating conditions.

It is believed that the non-uniform mechanical disturbances of the web in the table roll section of a conventional Fourdrinier paper machine are caused mainly by the after-effects of randomly spaced and non-uniform size drainage curtains which occur at the outgoing nip of the table rolls. Grooved table rolls have the ability to control these drainage curtains and thus greatly lessen the streaks in the paper web. By proper design of a Fourdrinier machine replacing at least a portion of the plain table rolls with helically grooved rolls in accordance with this invention, mechanical disturbances of the web caused by water curtains can greatly be lessened or eliminated, thus producing a uniform paper web.

We claim:

1. In a Fourdrinier papermaking machine having a breast roll, a couch roll spaced apart from said breast roll, an endless foraminous drainage support about said rolls on which paper pulp stock is deposited to form a web, and a plurality of table rolls between said breast roll and said couch roll supporting said foraminous drainage support, the improvement which comprises providing the supporting surface of at least one of said table rolls with a relatively narrow substantially uninterrupted helical indentation extending for the full width of the working surface of said table roll, the ratio of the surface width between the helices to the width of the indentation being at least approximately 4:1, and the depth of the indentation being sufficient to prevent any substantial drainage inducing suction therefrom.

2. The apparatus according to claim 1 in which said indentation has a width of approximately ½”, and a depth of at least approximately 3/16”.

3. In a Fourdrinier papermaking machine having a breast roll, a couch roll spaced apart from said breast roll, an endless foraminous drainage support about said rolls on which paper pulp stock is deposited to form a web, and a plurality of table rolls between said breast roll and said couch roll, supporting said foraminous drainage support, the improvement which comprises the supporting surface of at least one of said table rolls with a relatively narrow substantially uninterrupted right hand helical indentation extending for the full width of the working surface of said table roll, the ratio of the surface width between the helices to the width of the indentations being at least approximately 4:1, and the depth of the indentations being sufficient to prevent any substantial drainage inducing suction therefrom.

4. In a Fourdrinier papermaking machine having a breast roll, a couch roll spaced apart from said breast roll, an endless foraminous drainage support about said rolls on which paper pulp stock is deposited to form a web, and a plurality of table rolls between said breast roll and said couch roll, supporting said foraminous drainage support, the improvement which comprises the supporting surface of at least one of said table rolls with a relatively narrow substantially uninterrupted left hand helical indentation extending for the full width of the working surface of said table roll, the ratio of the surface width between the helices to the width of the indentations being at least approximately 4:1, and the depth of the indentations being sufficient to prevent any substantial drainage inducing suction therefrom.

5. The apparatus according to claim 4 in which the helical pitch of said indentation progressively increases from about ½” at the wetter portion of the drier two-thirds of the machine to about ¾” at the drier end of the machine.

6. The apparatus according to claim 4 which includes means to prevent drainage curtains from one table roll from contacting the succeeding table roll comprising a deflector plate mounted between adjacent table rolls and extending from a point just beneath the underside of the drainage support to a point below the horizontal plane formed by the centerline of said table roll.

7. The method of preventing non-uniform web disturbances in the table roll section of a Fourdrinier papermaking machine which comprises separating the induced drainage on at least one of said table rolls into a plurality of distinct portions, continuously and progressively shifting said drainage portions in a direction parallel to the centerline of said table roll as it rotates, separating the induced drainage on at least one of said table rolls other than said first mentioned table roll into a plurality of distinct portions, continuously and progressively shifting said drainage portions on said second mentioned table roll in a direction parallel to the centerline of said table roll and to the opposite direction from the movement of the drainage portions of said first mentioned roll as it rotates.

8. The method of preventing non-uniform web disturbances in the table roll section of a Fourdrinier papermaking machine which comprises separating the induced drainage on at least one of said table rolls other than said first mentioned table roll into a plurality of distinct portions, continuously and progressively shifting said drainage portions in a direction parallel to the centerline of said table roll as it rotates, reflecting said drainage portions in a downward direction away from the succeeding table roll, separating the induced drainage on at least one of said table rolls other than said first mentioned table roll into a plurality of distinct portions, continuously and pro-
gressively shifting said drainage portions on said second mentioned table roll in a direction parallel to the centerline of said table roll and to the opposite direction from the movement of the drainage portions of said first mentioned roll as it rotates, and deflecting said drainage portions in a downward direction away from the succeeding table roll.

9. The method of preventing non-uniform web disturbances in the table roll section of a Fourdrinier papermaking machine which comprises separating the induced drainage on each of said table rolls on the drier two-thirds of the machine into a plurality of distinct portions, continuously and progressively shifting said drainage portions in a direction parallel to the centerline of said table rolls in opposite directions on alternate table rolls, and deflecting said drainage portions on each table roll in a downward direction away from the succeeding table roll.

References Cited in the file of this patent

UNITED STATES PATENTS

541,336 Savory 6 June 18, 1895
1,957,963 Johnstone May 8, 1934

FOREIGN PATENTS

319,069 Germany Mar. 3, 1922

OTHER REFERENCES