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(54) A PROCESS FOR THE RESTRAINED DRYING OF A PAPER WEB

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PROCEDE DE SECHAGE SOUS CONTRAINTE D'UNE BANDE DE PAPIER

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EP 0 418 317 B2

Description

[0001] The present invention relates to a process for the restrained drying of a paper web extending successively through a wet end and a dry end of a dryer section of a papermaking machine, said dryer section comprising a single-tier drying section for drying the web during movement of the web downstream relative to the wet end of the dryer section, said process being of the kind which comprises the steps of:

> moving the paper web and a dryer felt contiguously to each other such that the web and felt wrap a portion of heated surfaces of a plurality of rotatable dryers of said single-tier drying section such that the web is disposed between the felt and the heated surfaces of said dryers;
>
> guiding the web and felt contiguously to each other around a plurality of vacuum guide rolls of said single-tier drying section, each vacuum guide roll of said plurality of vacuum guide rolls being disposed between adjacent dryers of said plurality of dryers such that the web is supported by the felt during passage of the web between the dryers and the vacuum guide rolls, the arrangement being such that the felt is disposed between the web and the vacuum guide rolls when the web and felt wrap around a portion of the surface of the vacuum guide rolls; and
>
> connecting the vacuum guide rolls to a source of vacuum such that a vacuum is applied to the web through the felt when the web and felt wrap around the vacuum guide rolls such that the web is drawn into close conformity with the felt when the web and felt wrap around the vacuum guide rolls.

[0002] Such a process is disclosed in the article headed "Advances in dryer section runnability", pages 65 - 69 in TAPPI Journal, Vol. 70, No. 9, September 1987. Norcross, CA, US.

[0003] The same process is disclosed also in each one of EP-A-0345266 and EP-A-0345291, both published on 13-12-89.

[0004] The afore-mentioned article indicates that a high vacuum of 1 kPa is produced by the vacuum transfer rolls to hold the web to the fabric around the rolls, thereby restraining the web against cross-machine directional shrinkage. A single-tier dryer section of the kind disclosed in the afore-mentioned article has been used at the wet end of the dryer section. The afore-mentioned article suggests to extend the single-tier concept through the entire dryer section. However, the shrinkage of the sheet is very low as it is dried from 40 to 60 percent dry. Once the sheet reaches 60 percent dry, the shrinkage increases and continues at a high rate until the sheet is essentially dry.

[0005] US-A-3868780 discloses a dryer section in which there are long felt draws between adjacent guide rolls so that cross-machine directional shrinkage is permitted. The guide rolls may have a perforated shell so as to permit them to operate as traverse flow dryers when a vacuum is generated within the loop of the felt which is guided alternately around drying cylinders and guide rolls. Since the felt has long spans uncovered by the web, air will be drawn through such uncovered felt spans, thereby reducing the level of the vacuum acting on the web significantly. As a result the vacuum is inadequate to inhibit cross-machine directional shrinkage both at the wet end and the dry end of the dryer section.

[0006] An object of the present invention is to restrain the web positively against cross-machine directional shrinkage during drying of the web in the dry end of the dryer section.

[0007] The object of the invention is achieved by a process of the kind defined above, wherein a vacuum level of 1.49 to 1.99 kPa (6 to 8 inches WC) is applied in the vacuum guide rolls around which the web travels once it has reached a dryness of approximately 60% and until it is essentially dry so that cross-machine direction shrinkage of the web during drying of the web in the dry end of the dryer section is inhibited.

[0008] An advantage of the invention is that cross-machine direction shrinkage is not only inhibited during passage of the web around the dryers but also around the vacuum guide rolls. Furthermore, the fact that the vacuum guide rolls are of a diameter considerably less than that of the dryers results in a joint run of the web and felt between the dryers and the guide rolls which is minimal so that the web is restrained against cross-machine direction shrinkage throughout most of the passage through the single-tier drying section.

[0009] The aforementioned sheet restraint reduces edge curl and cockle and the graininess of the resultant sheet at the edges thereof. Furthermore, by the provision of such sheet restraint, the slice opening in the headbox is able to be more uniform and the cross direction fiber orientation profile is improved.

[0010] More specifically, various laboratory and mill studies have been carried out in order to quantify the nonuniform cross directional sheet shrinkage which occurs during conventional drying processes. The aforementioned nonuniform shrinkage is responsible for nonuniformities in headbox slice profiles, in fiber orientation, and in the sheet elongation and tensile energy absorption.

[0011] Tensile energy absorption hereinafter referred to as TEA is defined in "The Dictionary of Paper" Fourth Edition, published 1980, as the energy absorbed when a paper specimen is stressed to rupture under tension. It is expressed in energy units per unit area eg kg-cm/ cm^2. It is useful in evaluating packaging materials subject to rough handling.

[0012] The continuous drying restraint has a direct effect on the finished sheet properties by controlling the cross-directional elongation and TEA profiles. Additionally, such reduced shrinkage reduces the cockles and graininess of the sheet edges.

[0013] The aforementioned dictionary defines cockles as "a puckered condition of the sheet resulting from nonuniform drying and shrinking; it usually appears on paper that has had very little restraint during drying."

[0014] Furthermore, graininess is defined in the aforementioned dictionary as small variations in the surface appearance of a paper or board, resulting from any of a variety of causes, such as impressions of wires or felts, irregular distribution of color, and uneven shrinkage in drying.

[0015] Also, by restraining the sheet from cross direction shrinkage, the opening of the slice lip of the headbox may be maintained more uniform and an improved cross direction fiber orientation profile is obtained as stated more particularly hereinafter.

[0016] The process according to the invention provides a transfer of the web between dryers with positive support and restraining the sheet with fabric pressure and roll vacuum. The combination of the aforementioned arrangement has improved sheet threading, machine runability, and sheet properties.

[0017] In a conventional dryer section. the wet paper is dried by intermittent contact with cast-iron, steam heated dryers. The thermal contact between the paper and the dryer is maintained by tensioned dryer fabrics which apply a pressure to the paper as it wraps the dryer.

[0018] The aforementioned fabric pressure not only improves the drying contact, but also applies a restraint to the paper to prevent shrinkage from occurring. Such restraint, however, is repeatedly released as the sheet passes through the open draws between conventional dryer cylinders as described hereinbefore.

[0019] The fabric pressure continues to provide some restraint in the machine direction by maintaining a machine direction draw, but in the cross-machine direction, the paper is virtually unrestrained. The paper shrinks freely in the cross direction particularly at the edges and somewhat less so near the center of the web where the sheet is at least partly restrained by the outer portions.

[0020] Such nonuniform cross-machine shrinkage gives rise to nonuniform cross-directional sheet properties such as stretch, TEA and tensile.

[0021] Stretch is defined in the aforementioned dictionary as "the elongation corresponding to the point of rupture in a tensile strength measurement; it is usually expressed as a percentage of the original length."

[0022] The high cross-directional edge shrinkage also aggravates the susceptibility of the sheet to edge cockle, curl and graininess.

[0023] The aforementioned dictionary defines curl as "the curvature developed when one side of a paper specimen is wetted; it was formally used as a measure of the degree of sizing."

[0024] The lack of shrinkage restraint also increases the hygroexpansivity and can also have an adverse effect on fiber orientation. Hygroexpansivity is defined in "The Dictionary of Paper" as "the change in dimension of paper that results from a change in the ambient relative humidity; it is commonly expressed as a percentage and is usually several times higher for the cross direction than for the machine direction. This property is of great importance in applications where the dimensions of paper sheets and cards or construction board (wallboard, acoustical tile, etc.) are critical."

[0025] In various mill trials, the first phase of such study was directed at quantifying the nonuniformity on commercial paper machines and then determining the effect that the nonuniform shrinkage has on the machine operation and on the finished sheet properties.

[0026] The cross-directional sheet shrinkage was determined by metering fine drops of ink onto the stock as it discharged from the slice lip of the headbox. The distance between marks at the wet end were then compared to the distances at the dry end to determine the cross-directional shrinkage profile.

[0027] Results for a fine paper machine are discussed hereinafter. The shrinkage was found to be highly nonuniform. and in fact almost parabolic. As expected, the highest shrinkage was found to occur at the edges, where the sheet has the least cross-directional restraint and the sheet shrinkage was the lowest near the center where the paper was at least partly restrained by the outer portions.

[0028] A cross-directional paper sample was then tested in the laboratory to determine the variations in sheet properties and these results are discussed in greater detail hereinafter. Such results show the machine direction stretch is very uniform in the cross direction because it is controlled by the machine direction draws. However, the cross-directional stretch is very nonuniform which appears to be a direct reflection of the cross-directional shrinkage. In other words, the highest stretch occurs at the edges where the sheet has experienced the greatest shrinkage.

[0029] The machine direction and cross direction tensile strength profiles were also measured for the same sample.

[0030] Tensile strength is defined in the aforementioned dictionary as "the maximum tensile stress developed in a specimen before rupture under prescribed conditions; it is usually expressed as force per unit width of the specimen."

[0031] As discussed hereinafter, the machine direction tensile was fairly uniform, again being affected in part by the machine direction draw which does not vary in the cross direction. However, the cross direction tensile profile is nonuniform and exhibits a slight hyperbolic configuration. The lowest tensile occurs near the sheet edges, again where the cross-direction shrinkage was the greatest.

[0032] From the aforementioned tests, it is also evident that an increase in cross-direction restraint, as experienced near the center of the machine. causes a reduction in stretch with a corresponding increase in tensile strength. Since the cross-direction tensile varies in the cross direction, while the machine direction tensile remains fairly uniform, the tensile ratio also varies, with the highest ratio occurring at the edges.

[0033] The tensile ratio is the ratio of the tensile in the cross direction to the tensile in the machine direction and will be discussed in detail hereinafter.

[0034] The TEA profiles were also measured for the sample. The cross-direction profile reflected the nonuniformity in cross-direction stretch. The TEA profile, however, does not exhibit quite as much variation as the cross-direction stretch, because the loss in stretch near the machine center is greatly offset by the increase in tensile strength.

[0035] The increased shrinkage which occurs near the edges also has an adverse effect on headbox performance. In order to produce a level basis weight profile at the reel, the slice opening must be closed down near the edges. Such closing down near the edges of the slice opening reduces the basis weight at the edges to compensate for the higher shrinkage which occurs near the edges. Such reduction in basis weight causes the paper to go through the press section and earlier dryer sections with light edges which eventually heavy up as the edges shrink.

[0036] Basis weight is defined in the aforementioned dictionary as "the weight in pounds of a ream cut to a specified basis size. The number of sheets in a ream is usually 500."

[0037] The aforementioned nonuniform slice opening is known to cause a distortion of the fiber orientation by inducing cross flows.

[0038] The fiber orientation was determined for the aforementioned sample by measuring the sonic modulus profile as discussed hereinafter. The fiber orientation is indicated as the angle of the primary axis of the modulus envelope from the machine direction. A positive angle indicates the fibers are oriented towards the back side of the web and a negative angle indicates the fibers are oriented towards the front side.

[0039] The fibers are all oriented towards machine center line as would be expected because the slice opening is closed down near the edges to compensate for edge shrinkage.

[0040] The aforementioned advantages obtained by restrained drying of the web are reflected in considerable commercial advantages over webs produced in nonrestrained drying sections.

[0041] A vacuum level of 1.49 to 1.99 kPa (6 to 8 inches water column) in the vacuum rolls is essentially equal to the restraint which is applied by the dryer fabric. Such vacuum level is also the level which is required for positive sheet restraint.

[0042] An embodiment of the present invention will be evident from the detailed description contained hereinafter taken in conjunction with the various figures of the drawings and graphs in which:-

Figure 1 is a side-elevational view of a typical prior art double-felted dryer section;

Figure 2 is a graph showing the percentage of shrinkage from the front to the back edge of the sheet;

Figure 3 is a graph comparing sheet elongation profiles in a machine direction and a cross-machine direction;

Figure 4 is a graph comparing the sheet tensile strength profiles in a machine direction and cross-machine direction;

Figure 5 is a graph showing the sheet tensile ratio profile from the front to the back edge of the sheet;

Figure 6 is a graph showing the sheet tensile energy absorption profiles from the front to the back edge of the sheet for the machine direction and the cross-machine direction respectively;

Figure 7 is a graph showing the dry weight of a sheet from the front to the back edge thereof;

Figure 8 shows a slice profile of a headbox with the opening profile configured such that a dry weight is obtained as shown in figure 7;

Figure 9 is a graph showing sheet fiber orientation profile from the front to the back edge of the sheet;

Figure 10 is a graph comparing machine direction to cross-machine direction shrinkage and the effects thereon of sheet vacuum restraint on such sheet shrinkage;

Figure 11 is a graph similar to that shown in figure 9 but showing the effect of sheet vacuum restraint on sample stretch;

Figure 12 is a graph showing the effect of sheet vacuum restraint on sample tensile strength;

Figure 13 is a graph showing the effect of sheet vacuum restraint on sample TEA;

Figure 14 is a side-elevational view of a single felt dryer-section or serpentine run or Uno-run dryer section;

Figure 15 is a side-elevational view of a TOTAL BEL RUN® single tier dryer section as described in EP-A-0345266 and EP-A-0345291;

Figure 16 is a graph showing sample shrinkage characteristics in a machine direction and in a cross-machine direction respectively;

Figure 17 is a graph showing the effect of restrained compared to nonrestrained on hygroexpansivity;

Figure 18 is a copy of a photomicrograph showing the surface of a freely dried sheet; and

Figure 19 is a photomicrograph showing the surface of a restraint dried sheet.

[0043] Similar reference characters refer to similar parts throughout the various embodiments shown in the drawings.

[0044] Figure 1 is a side-elevational view of a typical double-felted dryer section generally designated 10 including dryers 11 and 12 of an upper tier generally designated 13. The dryer section 10 also includes lower dryers 14 and 15 of a lower tier generally designated 16. The web W extends in sinusoidal configuration past dryers 14, 11, 15 and 12 respectively so that alternate sides of the web are dried as they come into contact with the respective external surfaces 17, 18, 19 and 20 of dryers14, 11, 15 and 12. An upper felt 21 extends around a guide roll 22 and then around dryer 11. The upper felt 21 then extends around a further guide 23 and the upper dryer 12. Similarly, a lower felt 24 after extending around dryer 14 extends around a lower guide roll 25 and dryer 15 and then around a further lower guide roll 26.

[0045] Although this prior art dryer section provides sheet restraint during passage around the respective upper and lower dryers 11, 12, 14 and 15, the web is unsupported and therefore unrestrained against shrinkage during transit of the web W between for example dryers 14 and 11. Such unsupported web is known in the art as an open draw 27. Because the web W is unsupported during transit through the open draws 27, cross-machine direction shrinkage of the web occurs with the attendant edge curl, graininess, and edge cockles.

[0046] Figure 2 is a graph showing the results for a fine paper machine wherein the shrinkage was found to be highly nonuniform with the graph being almost parabolic. As expected, the highest shrinkage was found to occur at the edges where the sheet has the least cross-directional restraint and the sheet shrinkage was the lowest near the center where the paper was at least partly restrained by the outer portion. In the graph of figure 2, the x axis includes readings taken from the front edge to the back edge of the sample web and the amount of shrinkage is shown as a percentage of the initial width.

[0047] Figure 3 is a graph showing a cross-directional paper sample tested in the laboratory to determine the variations in sheet properties. As shown in figure 3, the machine direction and cross-machine direction sheet strength profiles are demonstrated. The machine direction stretch is very uniform in the cross direction because it is controlled by the machine direction draws. However, the cross-machine direction stretch is very nonuniform as shown by the graph. From a comparison of the graph 28 with the graph 29 of the machine direction, it appears there is a direct reflection of the cross-direction shrinkage, that is the highest stretch occurs at the edges where the sheet has experienced the greatest shrinkage.

[0048] The graph shown in figure 4 includes a graph of the sheet tensile strength profiles for the cross-machine direction 30 and the graph for the machine direction 31. The machine direction tensile as shown in figure 4 is fairly uniform again being affected in part by the machine direction draw which does not vary in the cross-direction. The cross-direction tensile profile, however, is nonuniform. It exhibits a slight "frown" or hyperbolic shape. The lowest tensile occurs near the sheet edges again where the cross-machine direction shrinkage was the greatest.

[0049] From the above data it is clearly demonstrated that an increase in cross-machine direction restraint, as experienced near the center of the machine causes a reduction in stretch with a corresponding increase in tensile strength. Since the cross-machine direction tensile varies in the cross direction, while machine direction tensile remains fairly uniform, the tensile ratio also varies with the highest ratio occurring at the edges as shown by the tensile ratio graph 32 shown in figure 5.

[0050] Figure 6 shows two graphs 33 and 34. Graph 33 demonstrates the sheet TEA profile in a machine direction where graph 34 shows the sheet TEA profile for the cross-machine direction.

[0051] The TEA profiles also measured for the same sample. The cross-machine direction profile shown in figure 6 reflects the nonuniformity in the cross-machine direction stretch. The TEA profile, however, does not exhibit quite as much variation as the cross-machine direction stretch because the loss in stretch near the machine center is partly offset by the increase in the tensile strength.

[0052] Figure 7 is a graph 35 showing the dry weight of a sample sheet from the front to the back edge thereof.

[0053] Figure 8 is a graph showing the slice profile required in order to obtain the result shown in figure 7. As shown in figure 8 the slice openings are reduced at the respective edges in order to obtain a relatively uniform resultant web after shrinkage.

[0054] The fiber orientation was determined for the sample by measuring the sonic modulus profile. The profile is shown in figure 9 which is a graph from the front to the back of the sheet. The graph indicates actual readings whereas the graph 36 shows the average orientation. The fiber orientation is indicated as the angle of the primary axis of the modulus envelope from the machine direction. A positive angle indicates that the fibers are oriented towards the back side, and a negative angle indicates that the fibers are oriented towards the front side.

[0055] In the sample used, the fibers were all oriented towards the machine center line, as expected, because the slice opening was closed down near the edges to compensate for edge shrinkage.

<u>EXAMPLES</u>:

[0056] Numerous hand sheet trials in the laboratory were performed which indicated that increased sheet restraint during drying produces a reduction in stretch, an increase in tensile strength, and an increase in modulus.

[0057] In the trial, instead of using hand sheets, the samples were manufactured on pilot two-wire machines at commercial speeds. These sheets were then freely dried on a dryer fabric which was supported by a vacuum box. Separate sheets were dried with different levels of vacuum in the box to provide different levels of sheet shrinkage restraint.

[0058] With no vacuum in the box, the machine made sheet was able to shrink unrestrained. The total machine direction shrinkage was about 1% and the total cross-machine direction shrinkage was nearly 7%, as shown in figure 10. However, as the vacuum level (drying restraint) was increased. there was a progressive decrease in shrinkage.

[0059] The corresponding sheet properties for these samples are shown in figures 11 to 13 for stretch, tensile, and TEA. The same trends are seen in these properties as indicated by the mill trials. The increased cross-machine direction restraint (experienced by the center samples of the commercial machine and induced by the vacuum box in the laboratory studies) caused similar changes in the finished sheet properties.

[0060] More specifically, figure 10 shows the effect of sheet vacuum restraint on sheet shrinkage for machine directions as shown by graph 37 and for cross-machine direction as shown by graph 38.

[0061] Figure 11 shows the effect of sheet vacuum restraint on sample stretch and shows graph 39 for the machine direction and graph 40 for the cross-machine direction.

[0062] Figure 12 shows the effect of sheet vacuum restraint on sample tensile strength with the machine direction graph 41 and the cross-machine direction 42.

[0063] Figure 13 shows the effect of sheet vacuum restraint on sample TEA with graph 43 indicating machine direction and graph 44 showing cross-machine direction.

[0064] In order to achieve a level weight profile without a nonuniform slice opening, and in order to produce a sheet with uniform cross-direction property profiles, it is necessary to control the cross-machine direction shrinkage. Since the shrinkage occurs as the moisture is removed, the majority of the shrinkage takes place in the open draws where the water flashes. In order to reduce the shrinkage, the open draws must be replaced by a means of positive restraint as exemplified in EP-A-0345266 and EP-A-0345291.

[0065] A common commercial arrangement for eliminating open draws is the single felt or serpentine dryer section shown in figure 14.

[0066] In figure 14 dryers 100, 101 and 102 constitute an upper tier generally designated 103 whereas dryers 104 and 105 constitute a lower tier 106. A joint run of the web WA and felt F extends in serpentine configuration respectively around the dryers 100, 104, 101, 105 and 102. Although blow boxes 107 and 108 draw the web towards the felt during transit of the web between dryers, such vacuum is insufficient to cause any appreciable restraint of the web. Although this arrangement does eliminate the open draws, it does not replace the open draws with positive restraint and it dries the sheet from one side only.

[0067] Figure 15 shows the TOTAL BEL RUN@ arrangement disclosed in EP-A-0345266 and EP-A-0345921 including dryers 200. 201 and 202 arranged as a single tier generally designated 203. Interposed between the dryers 200 and 201 is a vacuum guide roll 204. Furthermore, another guide roll 205 is disposed between the dryers 201 and 202. In this design the bottom ineffective dryers of the serpentine section shown in figure 14 have been eliminated and replaced with vacuum rolls 204 and 205. Two-sided drying is maintained in this arrangement by alternating between top-felted and bottom-felted single tier sections as shown in EP-A-0345266 and EP-A-0345921.

[0068] The intermediate vacuum rolls 204 and 205 of the aforementioned single tier section 203 act much like the fabric vacuum box used in the afore-mentioned laboratory studies. This vacuum maintains the restraint which is applied by the dryer fabric pressure as the sheet is transferred between dryers.

[0069] The vacuum which is induced by conventional serpentine blow boxes is typically only 24.9 to 49.81 Pa (0.1 to 0.2 inches water column) and is clearly inadequate to provide significant shrinkage restraint as shown from figure 9. Additionally, this low level vacuum does not extend around the entire bottom dryer. With the long sheet length between top dryers, the sheet is left unrestrained for a significant portion of the drying cycle in the conventional serpentine dryer section.

[0070] A vacuum level of 1.49 to 1.99 kPa (6 to 8 inches WC) in the vacuum rolls is essentially equal to the restraint which is applied by the dryer fabric. It is also the vacuum level which is required for positive sheet restraint as indicated in figure 9.

[0071] In order to achieve the same property improvements on a commercial machine as those achieved in the above laboratory studies, the drying restraint must be applied in those sections where the sheet is shrinking the most. Specific laboratory tests were made on the pilot machine samples to determine the natural or unrestrained shrinkage characteristics. The results for one of these samples is shown in figure 16.

[0072] In figure 16 for the particular furnish. the machine direction and cross-machine direction shrinkage as indicated by graphs 300 and 301 respectively, shrinkage is very low as the sheet is dried from 40 to 60 percent dry. Once the sheet reaches 60% dry, the shrinkage increases and continues at a high rate until the sheet is essentially dry.

[0073] The serpentine and single tier dryers without vacuum guide rolls-have been applied to the wet end of the dryer section. This has been done in order to improve runability. However, based on the results of figure 16, the single tier dryer section should be applied near the dry end of the machine. For improved paper properties for best runability and sheet quality, the single tier dryer section configuration should be applied to the entire dryer section.

[0074] In addition to the aforementioned improvements in sheet quality resulting from sheet restraint during drying, recent work has indicated that sheets dried under restraint exhibit a significant reduction in hygroexpansivity. These results shown in figure 17, show that the sheet is more stable when it is dried under restraint and also that the sheet hygroexpansivity is virtually unaffected by changes in sheet density, that is from pressing and fines content as a result of the fining.

[0075] A sheet which is dried under a restraint is significantly different from one which is dried freely.

[0076] The reduction in shrinkage also reduces the susceptibility of the sheet to develop curl, cockle, and grainy edges. These sheet defects are all induced by hygroexpansivity and aggravated by nonuniformities in Z direction by the density, filler distribution, fines distribution, and fiber orientation. By reducing the hygroexpansivity, these defects can be greatly reduced or eliminated. Figure 17 shows the effect of restraint on hygroexpansivity, the upper graphs 400, 401 and 402 representing freely dried sheets and the graphs 403, 404 and 405 representing sheets dried under restraint.

[0077] The photomicrographs shown in figures 18 and 19 compare the fiber surface characteristics of a sheet taken from the center of the machine that is under partial cross-machine direction restraint to a sheet taken from the edges with unrestrained cross-machine direction. These micrographs show the same reduction in fiber kinks and caliper as seen in laboratory dried samples.

[0078] In summary, the cross-directional sheet shrinkage which occurs during the drying process is highly nonuniform. This nonuniform shrinkage directly affects the cross-machine direction stretch, tensile, modulus and TEA profiles. The greatest shrinkage occurs near the edges. In order to achieve a level basis weight profile at the reel, the headbox slice opening must be reduced near the edges to recompensate for the edge shrinkage. The nonuniform shrinkage thereby indirectly affects fiber orientation and a single tier dryer section with intermediate vacuum rolls can be used to control the cross-machine direction shrinkage. Vacuum levels in the intermediate rolls or guide rolls in the range 1.49 to 1.99 kPa (6 to 8 inches WC) will continue the restraint applied by the dryer fabric pressure and substantially reduce the edge shrinkage.

[0079] This control of shrinkage will produce more uniform cross-direction property profiles, allow the slice opening to remain level, reduce the cross-machine direction variations in fiber orientation and minimize any tendency for curl, cockle or grainy edges to develop. Also, the web is restrained during transfer between drying sections.

Claims

1. A process for the restrained drying of a paper web extending successively through a wet end and a dry end of a dryer section of a papermaking machine, said dryer section comprising a single-tier drying section (203) for drying the web during movement of the web downstream relative to the wet end of the dryer section, said process comprising the steps of:

    moving the paper web and a dryer felt contiguously to each other such that the web and felt wrap a portion of heated surfaces of a plurality of rotatable dryers (200, 201, 202) of said single-tier drying section (203) such that the web is disposed between the felt and the heated surfaces of said dryers;

    guiding the web and felt contiguously to each other around a plurality of vacuum guide rolls (204, 205) of said single-tier drying section (203), each vacuum guide roll of said plurality of vacuum guide rolls being disposed between adjacent dryers of said plurality of dryers (200, 201, 202) such that the web is supported by the felt during passage of the web between the dryers and the vacuum guide rolls, the arrangement being such that the felt is disposed between the web and the vacuum guide rolls when the web and felt wrap around a portion of the surface of the vacuum guide rolls; and

    connecting the vacuum guide rolls (204, 205) to a source of vacuum such that a vacuum is applied to the web through the felt when the web and felt wrap around the vacuum guide rolls such that the web is drawn into close conformity with the felt when the web and felt wrap around the vacuum guide rolls; wherein a vacuum level of 1.49 to 1.99 kPa (6 to 8 inches WC) is applied in the vacuum guide rolls (204, 205) around which the web travels once it has reached a dryness of approximately 60 % and until it is essentially dry so that cross-machine direction shrinkage of the web during drying of the web in the dry end of the dryer section is inhibited.

Patentansprüche

1. Verfahren zum schrumpfbehinderten Trocknen einer Papierbahn, die sich nacheinander durch ein nasses Ende und ein trockenes Ende einer Trokkenpartie einer Papiermaschine erstreckt, wobei die Trockenpartie einen einreihigen Trockenabschnitt (203) zum Trocknen der Bahn während der Bewegung der Bahn stromabwärts bezüglich des nassen Endes der Trockenpartie aufweist, wobei das Verfahren die folgenden Schritte aufweist:

    Bewegen der Papierbahn und eines Trockenfilzes in Anlage miteinander, derart, daß die Bahn und der Filz einen Teil der erhitzten Oberflächen einer Vielzahl an drehbaren Trocknern (200, 201,202) des einreihigen Trockenabschnitts (203) umschlingen, derart, daß die Bahn zwischen dem Filz und den erhitzten Oberflächen der Trockner angeordnet ist;

Leiten der Bahn und des Filzes in Anlage miteinander um eine Vielzahl an Saugleitwalzen (204,205) des einreihigen Trockenabschnitts (203) herum, wobei jede Saugleitwalze der Vielzahl an Saugleitwalzen zwischen benachbarten Trocknern der Vielzahl an Trocknern (200,201,202) angeordnet ist, derart, daß die Bahn von dem Filz während des Laufs der Bahn zwischen den Trocknern und den Saugleitwalzen gestützt wird, wobei die Anordnung so getroffen ist, daß der Filz zwischen der Bahn und den Saugleitwalzen angeordnet ist, wenn die Bahn und der Filz einen Teil der Oberfläche der Saugleitwalze umschlingen; und

Verbinden der Saugleitwalzen (204,205) mit einer Unterdruckquelle, derart, daß ein Unterdruck an der Bahn durch den Filz hindurch angelegt wird, wenn die Bahn und der Filz sich um die Saugleitwalzen schlingen, derart, daß die Bahn in enge Anlage an den Filz gezogen wird, wenn sich die Bahn und der Filz um die Saugwalzen herum schlingen; wobei ein Unterdruckniveau von 1,49 bis 1,99 kPa (6 bis 8 Zoll WS) in den Saugleitwalzen (204,205) angelegt wird, um die sich die Bahn bewegt, wenn sie einmal eine Trockenheit von annähernd 60% erreicht hat und bis sie im wesentlichen trocken ist, so daß die Schrumpfung der Bahn quer zur Maschinenrichtung während des Trocknens der Bahn im trockenen Ende der Trockenpartie gehemmt ist.

Revendications

1. Procédé pour le séchage restreint d'une nappe de papier s'étendant successivement à travers une extrémité humide et une extrémité sèche d'une section de sécherie d'une machine à papier, cette section de sécherie comprenant une section de séchage à un seul étage (203) pour sécher la nappe pendant le mouvement de cette nappe vers l'aval par rapport à l'extrémité humide de la section de sécherie, ce procédé comprenant les étapes consistant à déplacer la nappe de papier et un feutre sécheur en les maintenant contigus l'un à l'autre, de telle façon que la nappe et le feutre enveloppent une portion de surfaces chauffées d'une pluralité de cylindres sécheurs rotatifs (200,201,202) de la section de séchage à un seul étage (203) de telle façon que la nappe soit disposée entre le feutre et la surface chauffée, à guider ensuite la nappe et le feutre, contigus l'un à l'autre, autour d'une pluralité de cylindres de guidage à vide (204,205) de la section de séchage à un seul étage (203), chaque cylindre de guidage à vide de la pluralité de cylindres de guidage à vide étant disposé entre des cylindres sécheurs voisins de la pluralité de cylindres sécheurs (200,201,202), de telle façon que la nappe soit supportée par le feutre pendant le passage de la nappe entre le cylindre sécheur et les cylindres de guidage, l'agencement étant tel que le feutre soit disposé entre la nappe et les cylindres de guidage lorsque la nappe et le feutre sont enroulés autour d'une partie de la surface des cylindres de guidage à vide et à connecter les cylindres de guidage à vide (204,205) à une source de vide de telle façon qu'un vide soit appliqué à la nappe, à travers le feutre, lorsque la nappe et le feutre sont enroulés autour des cylindres de guidage à vide, si bien que la nappe est aspirée de manière à être en conformité étroite avec le feutre lorsque la nappe et le feutre sont enroulés autour des cylindres de guidage à vide, caractérisé en ce qu'un niveau de vide allant de 1,49 à 1,99 kPa (de 6 à 8 Pouces de colonne d'eau) est appliqué dans les cylindres de guidage à vide (204,205) autour desquels se déplace la nappe une fois qu'elle a atteint un état sec d'environ 60% et jusqu'à ce qu'elle soit essentiellement sèche si bien qu'un rétrécissement de la nappe dans le sens travers de la machine, pendant le séchage de la nappe dans l'extrémité sèche de la section de sécherie, est empêché.

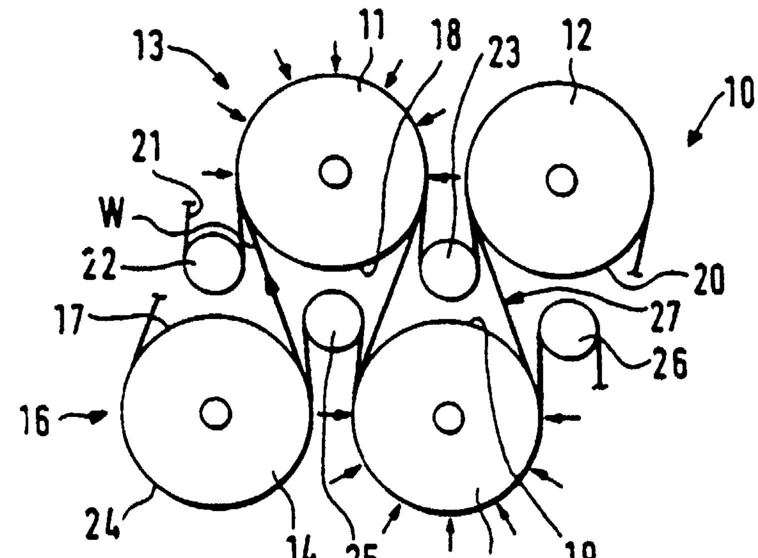

13
11
18
23
12
10
21
W
22
20
17
27
26
16
24
14
25
15
19

Fig.1

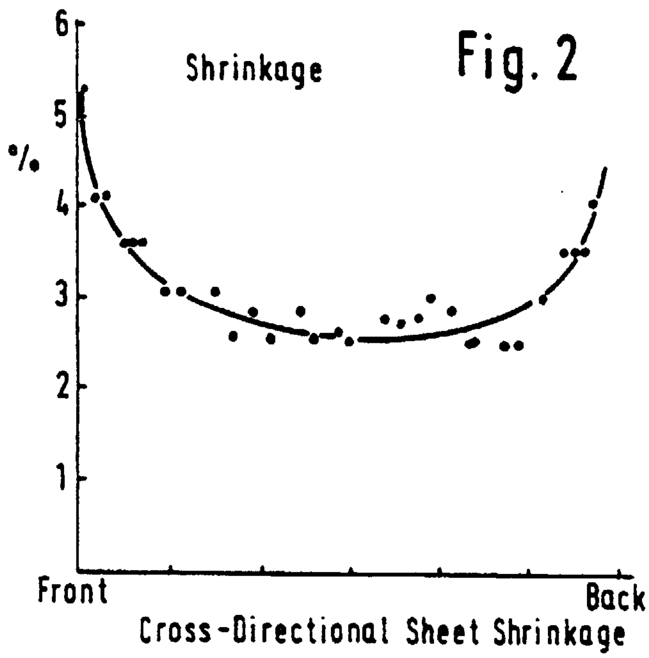

Shrinkage
%
6
5
4
3
2
1
Front
Back
Cross-Directional Sheet Shrinkage

Fig. 2

Fig.3

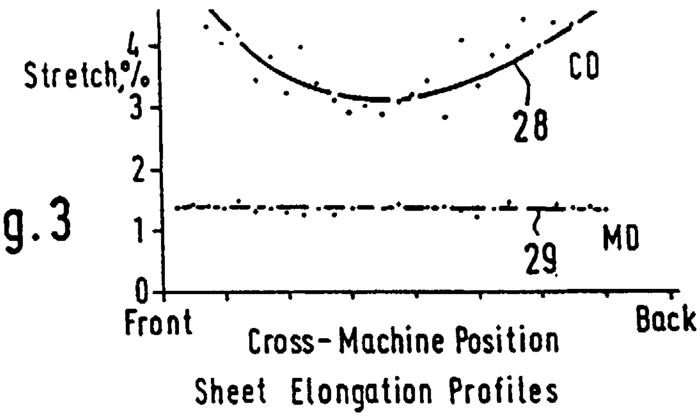


Fig.4

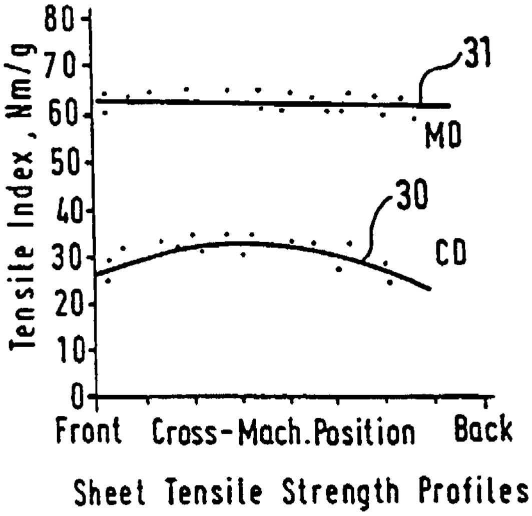


Fig.5

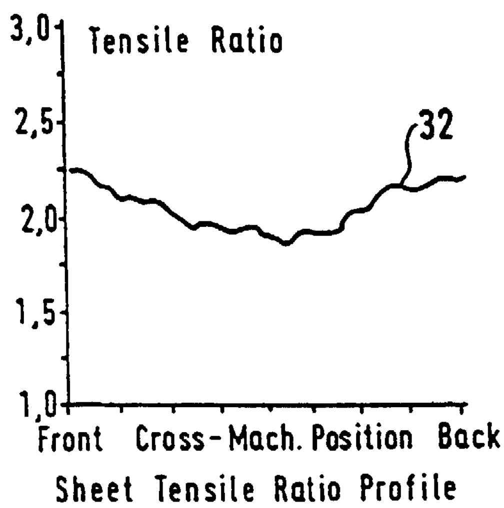
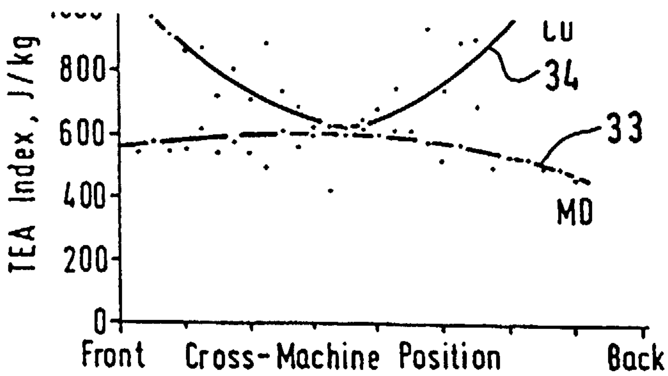
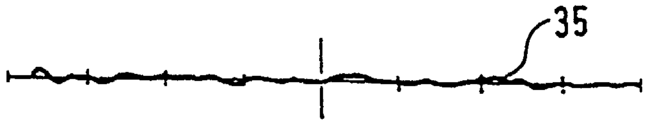


Fig. 6



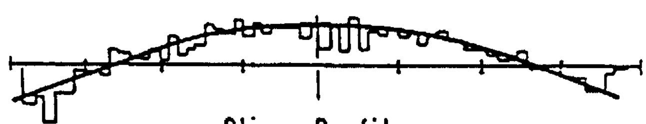
Sheet TEA Profiles

Fig. 7



Dry Weight 48±0.3 gsm

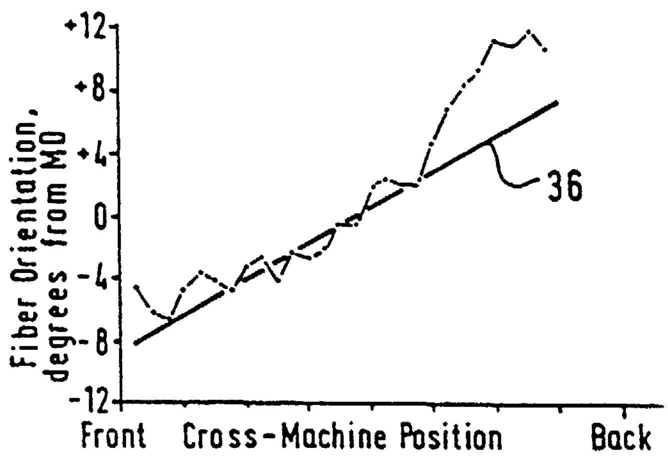
Fig. 8



Slice Profile

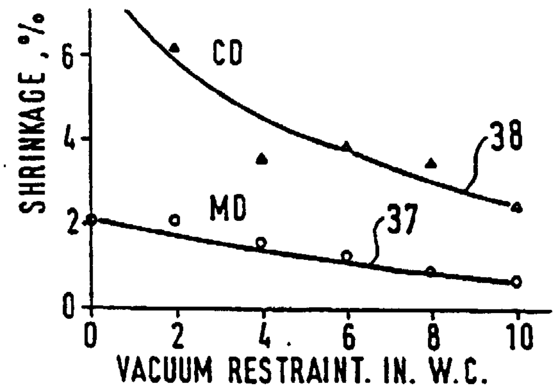
Headbox Slice Opening Profile

Fig. 9



Sheet Fiber Orientation Profile

Fig.10



Effect of Sheet Vacuum Restraint on Sheet Shrinkage

Fig. 11

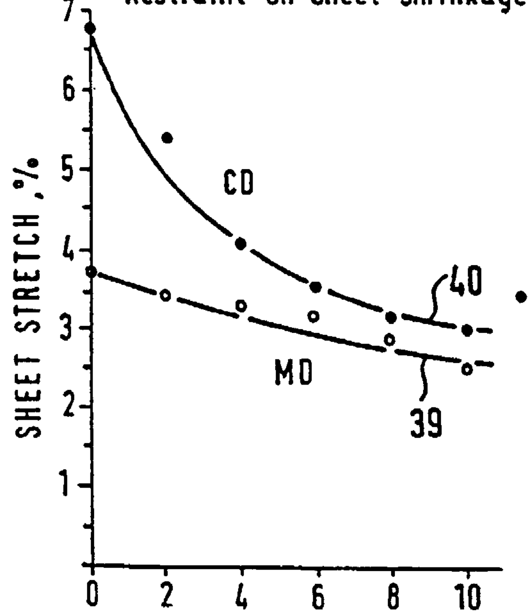
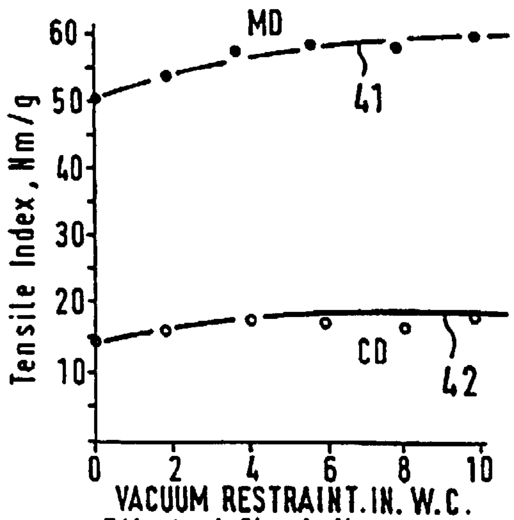
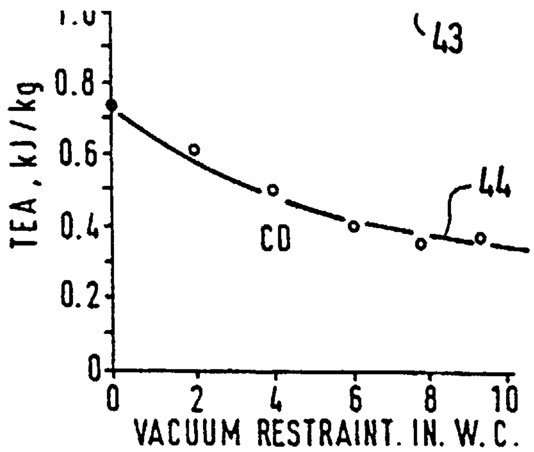


Fig.12



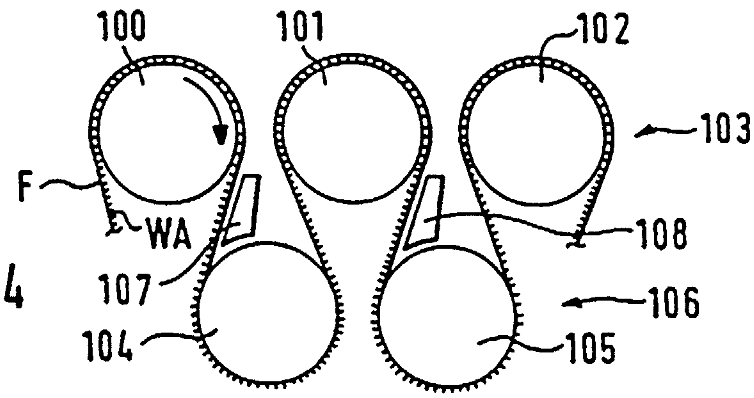
Effect of Sheet Vacuum Restraint on Sample Tensile Strength

Fig.13



Effect of Sheet Vacuum Restraint on Sample TEA

Fig.14



Single - Felt Dryer Section

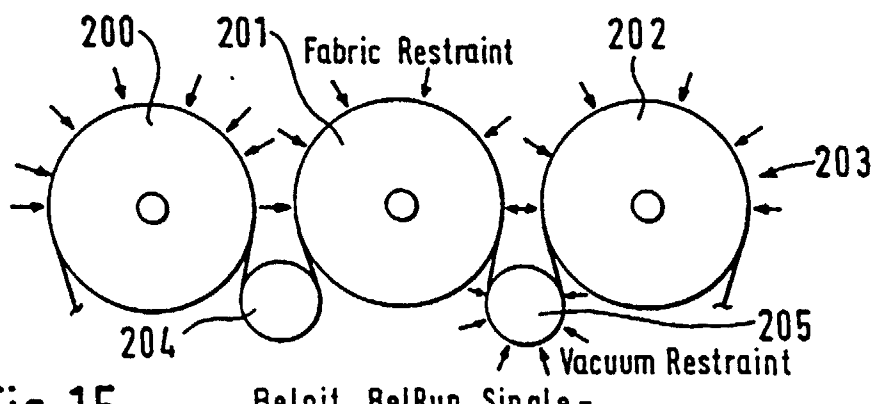


Fig.15

Beloit BelRun Single-Tier Dryer Section

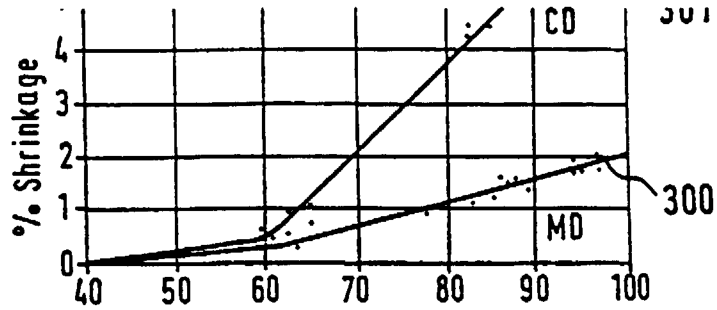


Fig. 16

Sample Shrinkage Characteristics

EFFECT OF REFINING

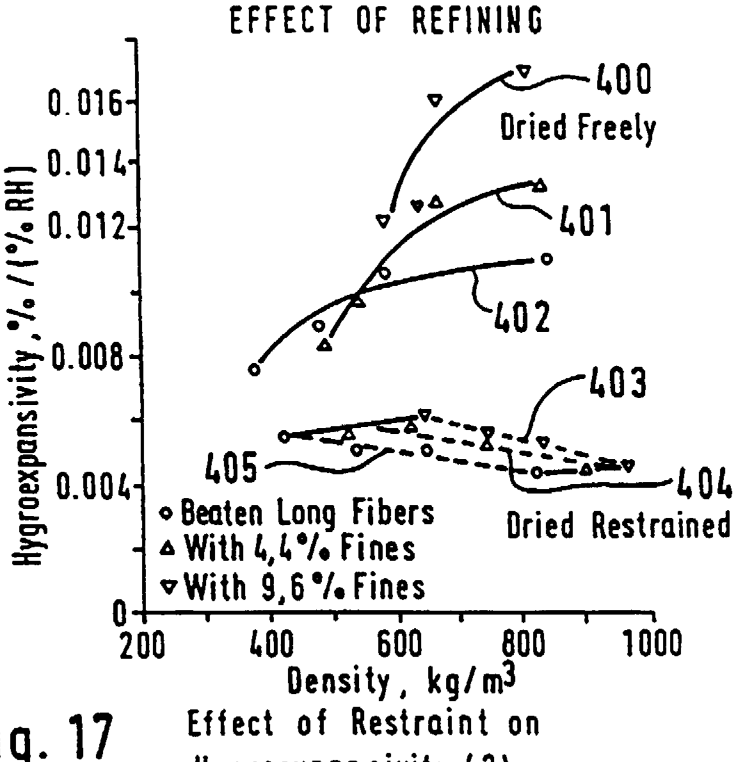


Fig. 17

Effect of Restraint on Hygroexpansivity (2)

FIG. 18

FIG. 19