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(54) **Eljárás szövetkreppelt, nedvszívó cellulózalap előállítására**

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(54) **Method of making a fabric-creped absorbent cellulosic sheet**

Verfahren zur Herstellung eines absorbierenden Tuchkrepp-Zellulosestoffes

Procédé de fabrication d'une feuille cellulosique absorbante en toile crêpée

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Description

[0001] This invention is directed, in part, to a process wherein a web is compactively dewatered, and creped into a creping fabric as stated in claim 1.

BACKGROUND

[0002] Methods of making paper tissue, towel, and the like are well known, including various features such as Yankee drying, throughdrying, fabric creping, dry creping, wet creping and so forth. Conventional wet pressing processes have certain advantages over conventional through-air drying processes including: (1) lower energy costs associated with the mechanical removal of water rather than transpiration drying with hot air; and (2) higher production speeds which are more readily achieved with processes which utilize wet pressing to form a web. On the other hand, through-air drying processing has been widely adopted for new capital investment, particularly for the production of soft, bulky, premium quality tissue and towel products.

[0003] Fabric creping has been employed in connection with papermaking processes which include mechanical or compactive dewatering of the paper web as a means to influence product properties. See U.S. Pat. Nos. 4,689,119 and 4,551,199 of Weldon; U.S. Pat. Nos. 4,849,054 and 4,834,838 of Klowak; and U.S. Pat. No. 6,287,426 of Edwards et al. Operation of fabric creping processes has been hampered by the difficulty of effectively transferring a web of high or intermediate consistency to a dryer. Note also U.S. Pat. No. 6,350,349 to Hermans et al. which discloses wet transfer of a web from a rotating transfer surface to a fabric. Further United States patents relating to fabric creping more generally include the following: U.S. Pat. Nos. 4,834,838; 4,482,429 4,445,638 as well as U.S. Pat. No. 4,440,597 to Wells et al.

[0004] In connection with papermaking processes, fabric molding has also been employed as a means to provide texture and bulk. In this respect, there is seen in U.S. Pat. No. 6,610,173 to Lindsey et al. a method for imprinting a paper web during a wet pressing event which results in asymmetrical protrusions corresponding to the deflection conduits of a deflection member. The ’173 patent reports that a differential velocity transfer during a pressing event serves to improve the molding and imprinting of a web with a deflection member. The tissue webs produced are reported as having particular sets of physical and geometrical properties, such as a pattern densified network and a repeating pattern of protrusions having asymmetrical structures. With respect to wet-molding of a web using textured fabrics, see, also, the following U.S. Pat. Nos. 6,017,417 and 5,672,248 both to Wendt et al.; U.S. Pat. Nos. 5,508,818 and 5,510,002 to Hermans et al. and U.S. Pat. No. 4,637,859 to Trokhan. With respect to the use of fabrics used to impart texture to a mostly dry sheet, see U.S. Pat. No. 6,585,855 to Drew et al., as well as United States Publication No. U.S. 2003/00064.

[0005] Throughdried, creped products are disclosed in the following patents: U.S. Pat. No. 3,994,771 to Morgan, Jr. et al.; U.S. Pat. No. 4,102,737 to Morton; and U.S. Pat. No. 4,529,480 to Trokhan. The processes described in these patents comprise, very generally, forming a web on a foraminous support, thermally pre-drying the web, applying the web to a Yankee dryer with a nip defined, in part, by an impression fabric, and creping the product from the Yankee dryer. A relatively permeable web is typically required, making it difficult to employ recycle furnish at levels which may be desired. Transfer to the Yankee typically takes place at web consistencies of from about 60% to about 70%. See also, U.S. Pat. No. 6,187,137 to Druecke et al. As to the application of vacuum while the web is in a fabric, the following are noted: U.S. Pat. No. 5,411,636 to Hermans et al.; U.S. Pat. No. 5,492,598 to Hermans et al.; U.S. Pat. No. 5,505,818 to Hermans et al.; U.S. Pat. No. 5,510,001 to Hermans et al.; and U.S. Pat. No. 5,510,002 to Hermans et al. US 2004/0238135 A1 discloses a process for making absorbent cellulosic paper products that includes compactively dewatering a nascent web followed by wet belt creping the web under conditions operative to redistribute fibers on the belt. The web is thereafter adhesively applied to a Yankee dryer using a specific creping adhesive.

[0006] As noted in the above, throughdried products tend to exhibit enhanced bulk and softness; however, thermal dewatering with hot air tends to be energy intensive. Wet-press operations wherein the webs are mechanically dewatered are preferable from an energy perspective and are more readily applied to furnishes containing recycle fiber which tends to form webs with less permeability than virgin fiber. Many improvements relate to increasing the bulk and absorbency of compactively dewatered products which are typically dewatered, in part, with a papermaking felt.

SUMMARY OF INVENTION

[0007] The present invention suggests a method of making a fabric-creped absorbent cellulosic sheet according to the features of claim 1. The dependent claims relate to advantageous features and embodiments of the invention.

[0008] Fabric-creped products of the present invention typically include fiber-enriched regions of relatively elevated basis weight linked together with regions of lower basis weight. Especially preferred products have a drawable reticulum which is capable of expanding, that is, increasing in void volume and bulk when drawn to greater length. This highly unusual and surprising property is further appreciated by considering the photomicrographs of FIGS. 1 and 2 as well as the data discussed in the Detailed Description section hereinafter.

[0009] A photomicrograph of the fiber-enriched region of an undrawn, fabric-creped web is shown in FIG. 1 which is in section along the MD (left to right in the photo). It is seen that the web has microfolds transverse to the machine direction, i.e., the ridges or creases extend in the CD (into the photograph). FIG. 2 is a photomicrograph of a web similar to FIG. 1, wherein the web has been drawn 45%. Here it is seen that the microfolds have been expanded, dispersing fiber from the fiber-enriched regions along the machine direction. Without intending to be bound by any theory, it is believed this feature of the invention, rearrangement or unfolding of the material in the fiber-enriched regions gives rise to the unique macroscopic properties exhibited by the material.

[0010] In order to better understand the invention while not forming part thereof, there is also disclosed herein a method of making a fabric-creped absorbent cellulosic sheet including the steps of: a) compactively dewatering a paper making furnish to form a nascent web having an apparently random distribution of paper making fiber; b) applying the dewatered web having the apparently random distribution to a translating transfer surface moving at a first speed; and c) fabric-creping the web from the transfer surface at a consistency of from about 30 to about 60 percent utilizing a patterned creping fabric, the creping step occurring under pressure in the fabric-creping nip defined between the transfer surface and the creping fabric wherein the fabric is traveling at a second speed slower than the speed of said transfer surface, the fabric pattern, nip parameters, velocity delta and web consistency being selected such that the web is creped from the transfer surface and redistributed on the creping fabric to form a web with a drawable reticulum having a plurality of regions of different local basis weights including at least (i) a plurality of fiber enriched regions of high local basis weight, interconnected by way of (ii) a plurality of lower local basis weight linking regions. The drawable reticulum of the web is characterized in that it comprises a cohesive fiber matrix capable of increasing in void volume when dried and subsequently drawn. Drawing the web increases the bulk of the web; decreases the sidedness of the web; and attenuates the fiber enriched regions of the web.

[0011] The method of making absorbent sheet according to the invention typically results with a non-random distribution of fibers in the web wherein the orientation of fibers in the fiber enriched regions are biased in the CD. It is apparent from the photomicrographs appended hereto, that orientation in the CD is strongest adjacent the fabric knuckle. The web is typically characterized in that the fiber enriched regions have a plurality of micro-folds with fold lines or creases transverse to the machine direction. Drawing the web in the machine direction expands the microfolds.

[0012] The process is generally operated at a fabric crepe of from about 10 to about 100 percent such as operated at a fabric crepe of at least about 40 percent. A fabric crepe of at least about 60 or 80 is preferred in some cases; however, the process may be operated at a fabric crepe of 100 percent or more, perhaps even in excess of 125 percent in some cases.

[0013] In order to better understand the invention while not forming part thereof, there is also disclosed herein a method of making a fabric-creped absorbent cellulosic sheet including the steps of: a) compactively dewatering a papermaking furnish to form a nascent web having an apparently random distribution of papermaking fiber; b) applying the dewatered web having the apparently random fiber distribution to a translating transfer surface moving at a first speed; c) fabric-creping the web from the transfer surface at a consistency of from about 30 to about 60 percent utilizing a patterned creping fabric, the creping step occurring under pressure in a fabric creping nip defined between the transfer surface and the creping fabric wherein the fabric is traveling at a second speed slower than the speed of said transfer surface. The fabric pattern, nip parameters, velocity delta and web consistency are selected such that the web is creped from the transfer surface and redistributed on the creping fabric to form a web with a drawable reticulum having a plurality of interconnected regions of different local basis weight including at least (i) a plurality of fiber enriched regions of high local basis weight, interconnected by way of (ii) a plurality of lower local basis weight linking regions. The drawable reticulum of the web is characterized in that it comprises a cohesive fiber matrix capable of increasing void volume upon dry-drawing. The process further includes: d) applying the web to a drying cylinder; e) drying the web on the drying cylinder; f) removing the web from the drying cylinder; wherein steps d, e and f are performed so as to substantially preserve the drawable fiber reticulum; and g) drawing the dried web. Preferably the drying cylinder is a Yankee dryer provided with a drying hood as is well known in the art. The web may be removed from the Yankee dryer without substantial creping. While a creping blade may or may not be used, it may be desirable in some cases to use a blade such as a non-metallic blade to gently assist or initiate removal of the web from a Yankee dryer.

[0014] In general, the process is operated at a fabric crepe of from about 10 to about 100 percent or even 200 or 300 percent fabric crepe and a crepe recovery of from about 10 to about 100 percent. As will be appreciated from the description which follows, crepe recovery is a measure of the amount of crepe which has been imparted to the web that has been subsequently pulled out. The process is operated at a crepe recovery of at least about 20 percent in preferred embodiments such as operated at a crepe recovery of at least about 30 percent, 40 percent, 50 percent, 60 percent, 80 percent, or 100 percent.

[0015] Any suitable paper making furnish may be employed to make the cellulosic sheet according to the present invention. The process is particularly adaptable for use with secondary fiber since the process is tolerant to fines. Most preferably the web is calendered and drawn on line.

[0016] While any suitable method may be used to draw the web, it is particularly preferred to draw the web between a first roll operated at a machine direction velocity greater than the creping fabric velocity and a second roll operated at a machine direction velocity greater than the first roll.

[0017] The fabric creped absorbent cellulosic sheet may be dried to a consistency of at least about 90 or even more preferably at least 92 percent prior to drawing. Typically, the web is dried to about 98% consistency when dried in-fabric.

[0018] Generally speaking, the processing parameters and fabric creping are controlled such that the ratio of percent decrease in caliper/percent decrease in basis weight of web is less than about 0.85 upon drawing web. A value of less than about 0.7 or even 0.6 is more preferred.

[0019] In order to better understand the invention while not forming part thereof, there is provided a method of making a fabric-creped absorbent cellulosic sheet including the steps of: a) compactively dewatering a papermaking furnish to form a nascent web having an apparently random distribution of papermaking fibers; b) applying the dewatered web having the apparently random fiber distribution to a translating transfer surface moving at a first speed; c) fabric-creping the web from the transfer surface at a consistency of from about 30 to about 60 percent utilizing a pattern creping fabric. The creping step occurs under pressure in a fabric-creping nip defined between the transfer surface and the creping fabric wherein the fabric is traveling at a second speed slower than the speed of the transfer surface. The fabric pattern, nip parameters, and velocity delta and web consistency are selected such that the web is creped from the transfer surface and redistributed on the creping fabric to form a web with a drawable reticulum having a plurality of interconnected regions of different local basis weights including at least: (i) a plurality of fiber enriched regions of high local basis weight, interconnected by way of (ii) a plurality of lower local basis weight linking regions. The drawable reticulum of the web is characterized in that it comprises a cohesive fiber matrix capable of increase in void volume upon dry-drawing. The process further includes the steps of: d) applying the web to a drying cylinder; e) drying the web on the drying cylinder; f) peeling the web from the drying cylinder; g) controlling the takeaway angle from the drying cylinder wherein steps d, e, f and g are performed so as to substantially preserve the drawable fiber reticulum. The dried web is then drawn to final length.

[0020] The step of controlling the take away angle from the drying cylinder may be carried out utilizing a sheet control cylinder. The sheet control cylinder is disposed adjacent to the drying cylinder such that the gap between the surface of the drying cylinder and the surface of the sheet control cylinder is less than about twice the thickness of the web. In preferred cases, the sheet control cylinder is disposed such that the gap between the surface of the drying cylinder and the surface of the sheet control cylinder is about the thickness of the web or less. Preferably, the web is calendered and drawn on line after being peeled from the drying cylinder.

[0021] The web is drawn by any suitable amount, depending on the desired properties. Generally the web is drawn by at least about 10 percent, usually by at least about 15 percent, suitably by at least about 30 percent. The web may be drawn by at least about 45 percent or 75 percent or more depending upon the amount of fabric crepe previously applied.

[0022] Any suitable method may be used in order to draw the web. One preferred method is to draw the web between a first draw roll operated at a first machine direction velocity which is desirably slightly greater than the creping fabric velocity and a second draw roll operated at a machine direction velocity substantially greater than the velocity of the first draw roll. When using this apparatus, the web advantageously wraps the first draw roll over an angle sufficient to control slip, ideally more than a 180° of its circumference. Likewise the web wraps the second draw roll over another angle sufficient to control slip, ideally more than 180° of its circumference as well. In preferred cases the web wraps each of the first and second draw rolls over from about 200° to about 300° of their respective circumferences. It is also preferred that the first and second draw rolls are moveable with respect to each other; such that they are going to be disposed in first position for threading and a second position for operation, one side of the web contacting the first draw roll and the other side of the web contacting the second draw roll.

[0023] In order to better understand the invention while not forming part thereof, there is also disclosed herein a method of making a fabric-creped absorbent cellulosic sheet including the steps of: a) compactively dewatering a papermaking furnish to form a nascent web having an apparently random distribution of papermaking fiber; b) applying the dewatered web having the apparently random fiber distribution to a transfer surface moving at a first speed; c) fabric-creping the web from the transfer surface at a consistency of from about 30 to about 60 percent utilizing a pattern creping fabric. The creping step is carried out under pressure in a fabric-creping nip defined between the transfer surface and the creping fabric wherein the fabric is traveling the second speed slower than the speed of the transfer surface. The fabric pattern, nip parameters, velocity delta, and web consistency are selected such that the web is creped from the transfer surface and redistributed on the creping fabric to form a web with a drawable reticulum having a plurality of interconnected regions of different local basis weight including at least (i) a plurality of fiber enriched regions of high local basis weight, interconnected by way of (ii) a plurality of lower local basis weight linking regions. The drawable reticulum of the web is characterized in that it includes a cohesive fiber matrix capable of increasing its void volume upon dry-drawing. The process further includes the steps of: d) adhering the web to a drying cylinder with a resinous adhesive coating composition; e) drying the web on the drying cylinder; and f) removing the web from the drying cylinder. Steps d, e and f are performed so as to substantially preserve the drawable fiber reticulum. After drying, the web is drawn to its final length.

[0024] The drying cylinder is optionally provided with a resinous protective coating layer underneath the resinous adhesive coating composition. The resinous protective coating layer preferably includes a polyamide resin; such as a diethylene triamine resin as is well known in the art. These resins may be cross-linked by any suitable means.

[0025] The resinous adhesive coating composition is preferably rewettable. The process is operated such that it includes maintaining the adhesive resin coating composition on the drying cylinder such that the coating provides sufficient wet tack strength upon transfer of the web to the drying cylinder to secure the web thereto during drying. The adhesive resin coating composition is also maintained such that the adhesive coating composition is pliant when dried such that the web may be removed from the drying cylinder without a creping blade. In this respect, "pliant" means that the adhesive resin coating composition does not harden when dried or is otherwise maintained in a flexible state such that the web may be separated from the drying cylinder without substantial damage. The adhesive coating composition may include a polyvinyl alcohol resin and preferably includes at least one additional resin. The additional resin may be a polysaccharide resin such as a cellulosic resin or a starch.

[0026] In order to better understand the invention while not forming part thereof, there is also disclosed herein a method of making a fabric-creped absorbent cellulosic sheet as described above wherein the web is embossed while it is disposed on the drying cylinder. After embossing, the web is further dried on the drying cylinder and removed therefrom. Preferably the steps of applying the web to the drying cylinder, embossing the web while it is disposed on the drying cylinder, drying the web on the drying cylinder and removing the web from the drying cylinder are performed so as to substantially preserve the drawable fiber reticulum. After removal from the drying cylinder, the dried web is drawn. The web is embossed at the drying cylinder when it has a consistency of less than about 80 percent; typically when it has a consistency of less than 70 percent; and preferably the web is embossed when its consistency is less than about 50 percent. In some cases it maybe possible to emboss the web while it is applied to the drying cylinder with an embossing surface traveling in the machine direction at a speed slower than the drying cylinder. In this method, additional crepe is applied to the web while it is disposed on the drying cylinder.

[0027] Applied vacuum is useful for increasing CD stretch. Another method of making a fabric-creped absorbent cellulosic sheet includes: a) compactively dewatering a papermaking furnish to form a nascent web having an apparently random distribution of papermaking fiber; b) applying the dewatered web having the apparently random fiber distribution to a translating transfer surface moving at a first speed; and c) fabric-creping the web from the transfer surface at a consistency of from about 30 to about 60 percent utilizing a creping fabric, the creping step occurring under pressure in a fabric creping nip defined between the transfer surface and the creping fabric wherein the fabric is traveling at a second speed slower than the speed of said transfer surface. The fabric pattern, nip parameters, velocity delta and web consistency are selected such that the web is creped from the transfer surface and redistributed on the creping fabric to form a web with a drawable reticulum having a plurality of interconnected regions of different local basis weights including at least (i) a plurality of fiber enriched regions of high local basis weight, interconnected by way of (ii) a plurality of lower local basis weight linking regions. The process also includes d) applying vacuum to the web to increase its CD stretch by at least about 5% with respect to a like web produced by like means without applied vacuum after fabric creping. Preferably, vacuum is applied to the web while it is held in the creping fabric and the creping fabric is selected to increase CD stretch when suitable levels of vacuum are applied to the web. Generally, at least 12.7 cm (5 inches) Hg of vacuum is applied; more typically at least 25.4 cm (10 inches) Hg of vacuum is applied when so desired. Higher vacuum levels such as at least 38.1 cm (15 inches) Hg or at least 50.8 (20 inches) Hg or at least 63.5 cm (25 inches) Hg of vacuum or more may be applied.

[0028] Applying vacuum to the web preferably increases the CD stretch of the web by at least about 5-7.5 percent with respect to a like web produced by the same means but without having vacuum applied thereto after fabric creping; more preferably, applying vacuum to the web increases the CD stretch of the web by at least about 10 percent with respect to a like web produced by the same means without having vacuum applied thereto after fabric creping. In still other examples, applying vacuum to the web increases the CD stretch of the web by at least about 20 percent with respect to a like web produced by the same means without having vacuum applied thereto after fabric creping; at least about 35 percent with respect to a like web produced by the same means without having vacuum applied thereto after fabric creping or at least about 50 percent with respect to a like web produced by the same means without having vacuum applied thereto after fabric creping being still more preferred in other cases.

[0029] The jet/wire velocity delta is an important parameter of the inventive method of claim 1. The jet/wire velocity delta may be greater than about 2.03 m/s (400 fpm), such as greater than about 2.23 m/s (450 fpm). Typically, the web has a reticulum with a plurality of interconnected regions of different local basis weights including at least (i) a plurality of fiber enriched regions of high local basis weight by way of (ii) a plurality of lower local basis weight linking regions. The orientation of fibers in the fiber enriched regions is biased in the CD.

[0030] Still yet other features and advantages of the invention will become apparent from the following description and appended drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0031] The invention is described in detail below with reference to the drawings, wherein like numerals designate similar parts:

FIG. 1 is a photomicrograph (120X) in section along the machine direction of a fiber-enriched region of a fabric-creped sheet which has not been drawn subsequent to fabric creping;

FIG. 2 is a photomicrograph (120X) in section along the machine direction of a fiber-enriched region of a fabric-creped sheet of the invention which has been drawn 45% subsequent to fabric creping.

FIG. 3 is a photomicrograph (10X) of the fabric side of a fabric-creped web which was dried in the fabric;

FIG. 4 is a photomicrograph (10X) of the fabric side of a fabric-creped web which was dried in-fabric then drawn 45%;

FIG. 5 is a photomicrograph (10X) of the dryer side of the web of FIG. 3;

FIG. 6 is a photomicrograph (10X) of the dryer side of the web of FIG. 4;

FIG. 7 is a photomicrograph (8x) of an open mesh web including a plurality of high basis weight regions linked by lower basis weight regions extending therebetween;

FIG. 8 is a photomicrograph showing enlarged detail (32x) of the web of FIG. 7;

FIG. 9 is a photomicrograph (8x) showing the open mesh web of FIG. 7 placed on the creping fabric used to manufacture the web;

FIG. 10 is a photomicrograph showing a web having a basis weight of 19 lbs/ream produced with a 17% Fabric Crepe;

FIG. 11 is a photomicrograph showing a web having a basis weight of 8.62 kg/500 sheets (19 lbs/ream) produced with a 40% Fabric Crepe;

FIG. 12 is a photomicrograph showing a web having a basis weight of 12.25 kg/500 sheets (27 lbs/ream) produced with a 28% Fabric Crepe;

FIG. 13 is a surface image (10X) of an absorbent sheet, indicating areas where samples for surface and section SEMs were taken;

FIGS. 14-16 are surface SEMs of a sample of material taken from the sheet seen in FIG. 13;

FIGS. 17 and 18 are SEMs of the sheet shown in FIG. 13 in section across the MD;

FIGS. 19 and 20 are SEMs of the sheet shown in FIG. 13 in section along the MD;

FIGS. 21 and 22 are SEMs of the sheet shown in FIG. 13 in section also along the MD;

FIGS. 23 and 24 are SEMs of the sheet shown in FIG. 13 in section across the MD;

FIG. 25 is a schematic diagram of a paper machine for practicing the process of the present invention;

FIG. 26 is a schematic diagram of another paper machine for practicing the process of the present invention;

FIG. 27 is a schematic diagram of portion of still yet another paper machine for practicing the process of the present invention;

FIGS. 28a and 28b are schematic diagrams illustrating an adhesive and protective coating for use in connection with the present invention;

FIGS. 29a and 29b are schematic diagrams illustrating draw rolls which can be used in connection with the paper machine of FIG. 27;

FIG. 30 is a schematic diagram of a portion of another paper machine provided with an embossing roll which embosses the web while it is adhered to the Yankee cylinder.

FIG. 31 is a plot of void volume versus basis weight as webs are drawn;

FIG. 32 is a diagram showing the machine direction modulus of webs of the invention wherein the abscissa have been shifted for purposes of clarity;

FIG. 33 is a plot of machine direction modulus versus percent stretch for products of the present invention;

FIG. 34 is a plot of caliper change versus basis weight change for various products of the invention;

FIG. 35 is a plot of caliper versus applied vacuum for fabric-creped webs;

FIG. 36 is a plot of caliper versus applied vacuum for fabric-creped webs and various creping fabrics;

FIG. 37 is a plot of TMI Friction values versus draw for various webs of the invention;

FIG. 38 is a plot of void volume change versus basis weight change for various products; and

FIG. 39 is a diagram showing representative curves of MD/CD tensile ratio versus jet to wire velocity delta for the products of the invention and conventional wet press (CWP) absorbent sheet.

DETAILED DESCRIPTION

[0032] The invention is described in detail below with reference to several embodiments and numerous examples. Such discussion is for purposes of illustration only. Modifications to particular examples within the spirit and scope of the present invention, set forth in the appended claims, will be readily apparent to one of skill in the art.

[0033] Terminology used herein is given its ordinary meaning consistent with the exemplary definitions set forth immediately below.

[0034] Throughout this specification and claims, when we refer to a nascent web having an apparently random distribution of fiber orientation (or use like terminology), we are referring to the distribution of fiber orientation that results when known forming techniques are used for depositing a furnish on the forming fabric. When examined microscopically, the fibers give the appearance of being randomly oriented even though, depending on the jet to wire speed, there may be a significant bias toward machine direction orientation making the machine direction tensile strength of the web exceed the cross-direction tensile strength.

[0035] Unless otherwise specified, "basis weight", BWT, bwt and so forth refers to the weight of a 3000 square foot ream of product. Consistency refers to percent solids of a nascent web, for example, calculated on a bone dry basis. "Air dry" means including residual moisture, by convention up to about 10 percent moisture for pulp and up to about 6% for paper. A nascent web having 50 percent water and 50 percent bone dry pulp has a consistency of 50 percent.

[0036] The term "cellulosic", "cellulosic sheet" and the like is meant to include any product incorporating papermaking fiber having cellulose as a major constituent. "Papermaking fibers" include virgin pulps or recycle (secondary) cellulosic fibers or fiber mixes comprising cellulosic fibers. Fibers suitable for making the webs of this invention include: nonwood fibers, such as cotton fibers or cotton derivatives, abaca, kenaf, sabai grass, flax, esparto grass, straw, jute hemp, bagasse, milkweed floss fibers, and pineapple leaf fibers; and wood fibers such as those obtained from deciduous and coniferous trees, including softwood fibers, such as northern and southern softwood kraft fibers; hardwood fibers, such as eucalyptus, maple, birch, aspen, or the like. Papermaking fibers can be liberated from their source material by any one of a number of chermical pulping processes familiar to one experienced in the art including sulfate, sulfite, polysulfide, soda pulping, etc. The pulp can be bleached if desired by chemical means including the use of chlorine, chlorine dioxide, oxygen, alkaline peroxide and so forth. The products of the present invention may comprise a blend of conventional fibers (whether derived from virgin pulp or recycle sources) and high coarseness lignin-rich tubular fibers, such as bleached chemical thermomechanical pulp (BCTMP). "Furnishes" and like terminology refers to aqueous compositions including papermaking fibers, optionally wet strength resins, debonders and the like for making paper products.

[0037] As used herein, the term compactively dewatering the web or furnish refers to mechanical dewatering by wet pressing on a dewatering felt, for example, in some embodiments by use of mechanical pressure applied continuously over the web surface as in a nip between a press roll and a press shoe wherein the web is in contact with a papermaking felt. The terminology "compactively dewatering" is used to distinguish processes wherein the initial dewatering of the web is carried out largely by thermal means as is the case, for example, in U.S. Pat. No. 4,529,480 to Trokhan and U.S. Pat. No. 5,607,551 to Farrington et al. noted above. Compactively dewatering a web thus refers, for example, to removing water from a nascent web having a consistency of less than 30 percent or so by application of pressure thereto and/or increasing the consistency of the web by about 15 percent or more by application of pressure thereto.

[0038] Creping fabric and like terminology refers to a fabric or belt which bears a pattern suitable for practicing the process of the present invention and preferably is permeable enough such that the web may be dried while it is held in the creping fabric. In cases where the web is transferred to another fabric or surface (other than the creping fabric) for drying, the creping fabric may have lower permeability.

[0039] "Fabric side" and like terminology refers to the side of the web which is in contact with the creping and drying fabric. "Dryer side" or "can side" is the side of the web opposite the fabric side of the web.

[0040] Fpm refers to feet per minute while consistency refers to the weight percent fiber of the web.

[0041] Jet/wire velocity delta is the difference in speed between the headbox jet issuing from a headbox (such as headbox 70, FIGS. 25, 26) and the forming wire or fabric; jet velocity-wire speed typically in fpm. In cases where a pair of forming fabrics are used, the speed of the fabric advancing the web in the machine direction is used to calculate jet/wire velocity delta, i.e., fabric 54, FIG. 25 or felt 78, FIG. 26 in the case of a crescent-forming machine. In any event, both forming fabrics are ordinarily at the same speed.

[0042] A "like" web produced by "like" means refers to a web made from substantially identical equipment in substantially the same way; that is with substantially the same overall crepe, fabric crepe, nip parameters and so forth.

[0043] MD means machine direction and CD means cross-machine direction.

[0044] Nip parameters include, without limitation, nip pressure, nip length, backing roll hardness, fabric approach angle, fabric takeaway angle, uniformity, and velocity delta between surfaces of the nip.

[0045] Nip length means the length over which the nip surfaces are in contact.

[0046] The drawable reticulum is "substantially preserved" when the web is capable of exhibiting a void volume increase upon drawing.

[0047] "On line" and like terminology refers to a process step performed without removing the web from the paper machine in which the web is produced. A web is drawn or calendered on line when it is drawn or calendered without being severed prior to wind-up.

[0048] "Pliant" in the context of the creping adhesive means that the adhesive resin coating composition does not harden when dried or is otherwise maintained in a flexible state such that the web may be separated from the drying cylinder without substantial damage. The adhesive coating composition may include a polyvinyl alcohol resin and preferably includes at least one additional resin. The additional resin may be a polysaccharide resin such as a cellulosic resin or a starch.

[0049] A translating transfer surface refers to the surface from which the web is creped into the creping fabric. The translating transfer surface may be the surface of a rotating drum as described hereafter, or may be the surface of a continuous smooth moving belt or another moving fabric which may have surface texture and so forth. The translating transfer surface needs to support the web and facilitate the high solids creping as will be appreciated from the discussion which follows.

[0050] Calipers and or bulk reported herein may be measured 1, 4 or 8 sheet calipers as specified. The sheets are stacked and the caliper measurement taken about the central portion of the stack. Preferably, the test samples are conditioned in an atmosphere of 23 ± 1.0°C. (73.4° ± 1.8°F.) at 50% relative humidity for at least about 2 hours and then measured with a Thwing-Albert Model 89-II-JR or Progage Electronic Thickness Tester with 50.8-mm (2-in) diameter anvils, 539 ± 10 grams dead weight load, and 5.87 mm/sec (0.231 in./sec) descent rate. For finished product testing, each sheet of product to be tested must have the same number of plies as the product is sold. For testing in general, eight sheets are selected and stacked together. For napkin testing, napkins are unfolded prior to stacking. For basesheet testing off of winders, each sheet to be tested must have the same number of plies as produced off the winder. For basesheet testing off of the paper machine reel, single plies must be used. Sheets are stacked together aligned in the MD. On custom embossed or printed product, try to avoid taking measurements in these areas if at all possible. Bulk may also be expressed in units of volume/weight by dividing caliper by basis weight.

[0051] Absorbency of the inventive products is measured with a simple absorbency tester. The simple absorbency tester is a particularly useful apparatus for measuring the hydrophilicity and absorbency properties of a sample of tissue, napkins, or towel. In this test a sample of tissue, napkins, or towel 5.1 cm (2.0 inches) in diameter is mounted between a top flat plastic cover and a bottom grooved sample plate. The tissue, napkin, or towel sample disc is held in place by a 3.18mm (1/8 inch) wide circumference flange area. The sample is not compressed by the holder. Deionized water at 22.8°C (73°F.) is introduced to the sample at the center of the bottom sample plate through a 1 mm. diameter conduit. This water is at a hydrostatic head of minus 5 mm. Flow is initiated by a pulse introduced at the start of the measurement by the instrument mechanism. Water is thus imbibed by the tissue, napkin, or towel sample from this central entrance point radially outward by capillary action. When the rate of water imbibation decreases below 0.005 gm water per 5 seconds, the test is terminated. The amount of water removed from the reservoir and absorbed by the sample is weighed and reported as grams of water per square meter of sample or grams of water per gram of sheet. In practice, an M/K Systems Inc. Gravimetric Absorbency Testing System is used. This is a commercial system obtainable from M/K Systems Inc., 12 Garden Street, Danvers, Mass., 01923. WAC or water absorbent capacity also referred to as SAT is actually determined by the instrument itself. WAC is defined as the point where the weight versus time graph has a "zero" slope, i.e., the sample has stopped absorbing. The termination criteria for a test are expressed in maximum change in water weight absorbed over a fixed time period. This is basically an estimate of zero slope on the weight versus time graph. The program uses a change of 0.005 g over a 5 second time interval as termination criteria; unless "Slow SAT" is specified in which case the cut off criteria is 1 mg in 20 seconds.

[0052] Dry tensile strengths (MD and CD), stretch, ratios thereof, modulus, break modulus, stress and strain are measured with a standard Instron test device or other suitable elongation tensile tester which may be configured in various ways, typically using 7.62cm or 2.54 cm (3 or 1 inch) wide strips of tissue or towel, conditioned in an atmosphere of 23° ± 1°C. (73.4° ± 1°F.) at 50% relative humidity for 2 hours. The tensile test is run at a crosshead speed of 5.1 cm/min. (2 in/min.) Modulus is expressed in lbs/inch per inch of elongation unless otherwise indicated.

[0053] Tensile ratios are simply ratios of the values determined by way of the foregoing methods. Unless otherwise specified, a tensile property is a dry sheet property.

[0054] "Fabric crepe ratio" is an expression of the speed differential between the creping fabric and the forming wire and typically calculated as the ratio of the web speed immediately before fabric creping and the web speed immediately following fabric creping, the forming wire and transfer surface being typically, but not necessarily, operated at the same speed:

$$\text{Fabric crepe ratio} = \text{transfer cylinder speed/creping fabric speed}$$

[0055] Fabric crepe can also be expressed as a percentage calculated as:

$$\text{Fabric crepe, percent,} = [\text{Fabric crepe ratio}-1]*100\%$$

[0056] A web creped from a transfer cylinder with a surface speed of 13.72 km/h (750 fpm) to a fabric with a velocity of 9.14 km/h (500 fpm) has a fabric crepe ratio of 1.5 and a fabric crepe of 50%.

[0057] The draw ratio is calculated similarly, typically as the ratio of winding speed to the creping fabric speed. Draw may be expressed as a percentage by subtracting 1 from the draw ratio and multiply by 100%. The "pullout" or "draw" applied to a test specimen is calculated from the ratio of final length divided by its length prior to elongation. Unless otherwise specified, draw refers to elongation with respect to the length of the as-dried web. This quantity may also be expressed as a percentage. For example a 10.2 cm (4") test specimen drawn to 12.7 cm (5") has a draw ratio of 5/4 or 1.25 and a draw of 25%.

[0058] The total crepe ratio is calculated as the ratio of the forming wire speed to the reel speed and a % total crepe is:

$$\text{Total Crepe \%} = [\text{Total Crepe Ratio}-1]*100\%$$

[0059] A process with a forming wire speed of 36.58 km/h (2000 fpm) and a reel speed of 18.29 km/h (1000 fpm) has a line or total crepe ratio of 2 and a total crepe of 100%.

[0060] The recovered crepe of a web is the amount of fabric crepe removed when the web is elongated or drawn. This quantity is calculated as follows and expressed as a percentage:

$$\text{Recovered Crepe \%} = [\ 1 - \%\text{Total Crepe} / \%\ \text{Fabric Crepe}]\ \text{x}\ 100\%$$

[0061] A process with a total crepe of 25% and fabric crepe of 50% has a recovered crepe of 50%.

[0062] Recovered crepe is referred to as the crepe recovery when quantifying the amount of crepe and draw applied to a particular web. Sample calculations of the various quantities for a paper machine 40 of the type shown in FIG. 25 provided with a transfer cylinder 90, a creping fabric 48 as well as a take up reel 120 are given in Table 1 below. Recovered fabric crepe is a product attribute which relates to bulk and void volume as is seen in the Figures and Examples below. Speed values given in fpm can be multiplied with 0.018 in order to obtain the corresponding value in km/h.

Table 1 - Sample Calculations of Fabric Crepe, Draw and Recovered Crepe

Wire fpm	Crepe Fabric fpm	Reel fpm	FCRatio	FabCrp% %	DrawRatio	Draw% %	TotalCrp Ratio	ToCrptPct %	RecCrp %
1000	500	750	2.00	100%	1.5	50%	1.33	33%	67%
2000	1500	1600	1.33	33%	1.067	6.7%	1.25	25%	25%
2000	1500	2000	1.33	33%	1.33	33%	1.00	0%	100%
3000	1500	2625	2.00	100%	1.75	75%	1.14	14%	86%
3000	2000	2500	1.50	50%	1.25	25%	1.20	20%	60%

[0063] Friction values and sidedness are calculated by a modification to the TMI method discussed in U.S. Pat. No. 6,827,819 to Dwiggins et al., this modified method is described below. A percent change in friction value or sidedness upon drawing is based on the difference between the initial value without draw and the drawn value, divided by the initial value and expressed as a percentage.

[0064] Sidedness and friction deviation measurements can be accomplished using a Lab Master Slip & Friction tester, with special high-sensitivity load measuring option and custom top and sample support block, Model 32-90 available from:

Testing Machines Inc.
2910 Expressway Drive South
Islandia, N.Y. 11722
800-678-3221
www.testingmachines.com

adapted to accept a Friction Sensor, available from:

Noriyuki Uezumi
Kato Tech Co., Ltd.
Kyoto Branch Office
Nihon-Seimei-Kyoto-Santetsu Bldg. 3F
Higashishiokoji-Agaru, Nishinotoin-Dori
Shimogyo-ku, Kyoto 600-8216
Japan
81-75-361-6360
katotech@mx1.alpha-web.ne.jp

[0065] The software for the Lab Master Slip and Friction tester is modified to allow it to: (1) retrieve and directly record instantaneous data on the force exerted on the friction sensor as it moves across the samples; (2) compute an average for that data; (3) calculate the deviation-absolute value of the difference between each of the instantaneous data points and the calculated mean; and (4) calculate a mean deviation over the scan to be reported in grams.

[0066] Prior to testing, the test samples should be conditioned in an atmosphere of 23.0° ± 1°C (73.4° ± 10.8°F.) and 50% ± 2% R.H. Testing should also be conducted at these conditions. The samples should be handled by edges and corners only and any touching of the area of the sample to be tested should be minimized as the samples are delicate, and physical properties may be easily changed by rough handling or transfer of oils from the hands of the tester.

[0067] The samples to be tested are prepared, using a paper cutter to get straight edges, as 7.62 cm (3-inch) wide (CD) by 12.7 cm (5-inch) long (MD) strips; any sheets with obvious imperfections being removed and replaced with acceptable sheets. These dimensions correspond to those of a standard tensile test, allowing the same specimen to be first elongated in the tensile tester, then tested for surface friction.

[0068] Each specimen is placed on the sample table of the tester and the edges of the specimen are aligned with the front edge of the sample table and the chucking device. A metal frame is placed on top of the specimen in the center of the sample table while ensuring that the specimen is flat beneath the frame by gently smoothing the outside edges of the sheet. The sensor is placed carefully on the specimen with the sensor arm in the middle of the sensor holder. Two MD-scans are run on each side of each specimen.

[0069] To compute the TMI Friction Value of a sample, two MD scans of the sensor head are run on each side of each sheet, where The Average Deviation value from the first MD scan of the fabric side of the sheet is recorded as MDF1; the result obtained on the second scan on the fabric side of the sheet is recorded as MDF2. MDD1 and MDD2 are the results of the scans run on the Dryer side (Can or Yankee side) of the sheet.

[0070] The TMI Friction Value for the fabric side is calculated as follows:

$$TMI\_FV_F = \frac{MD_{F1} + MD_{F2}}{2}$$

[0071] Likewise, the TMI Friction Value for the dryer side is calculated as:

$$TMI\_FV_D = \frac{MD_{D1} + MD_{D2}}{2}$$

[0072] An overall Sheet Friction Value can be calculated as the average of the fabric side and the dryer side, as follows:

$$TMI\_FV_{AVG} = \frac{TMI\_FV_F + TMI\_FV_D}{2}$$

[0073] Leading to Sidedness as an indication of how much the friction differs between the two sides of the sheet. The sidedness is defined as:

$$Sidedness = \frac{TMI\_FV_U}{TMI\_FV_L} * TMI\_FV_{AVG}$$

here "U" and "L" subscripts refer to the upper and lower values of the friction deviation of the two sides (Fabric and Dryer)-that is the larger Friction value is always placed in the numerator.

[0074] For fabric-creped products, the fabric side friction value will be higher than the dryer side friction value. Sidedness takes into account not only the relative difference between the two sides of the sheet but the overall friction level. Accordingly, low sidedness values are normally preferred.

[0075] PLI or pli means pounds force per linear inch.

[0076] Pusey and Jones (P&J) hardness (indentation) is measured in accordance with ASTM D 531, and refers to the indentation number (standard specimen and conditions).

[0077] Velocity delta means a difference in linear speed.

[0078] The void volume and/or void volume ratio as referred to hereafter, are determined by saturating a sheet with a nonpolar POROFIL(R) liquid and measuring the amount of liquid absorbed. The volume of liquid absorbed is equivalent to the void volume within the sheet structure. The percent weight increase (PWI) is expressed as grams of liquid absorbed per gram of fiber in the sheet structure times 100, as noted hereinafter. More specifically, for each single-ply sheet sample to be tested, select 8 sheets and cut out a 2.54 cm by 2.54 cm (1 inch by 1 inch square) (2.54 cm (1 inch) in the machine direction and 2.54 cm (1 inch) in the cross-machine direction). For multi-ply product samples, each ply is measured as a separate entity. Multiple samples should be separated into individual single plies and 8 sheets from each ply position used for testing. Weigh and record the dry weight of each test specimen to the nearest 0.0001 gram. Place the specimen in a dish containing POROFIL(R) liquid having a specific gravity of 1.875 grams per cubic centimeter, available from Coulter Electronics Ltd., Northwell Drive, Luton, Beds, England; Part No. 9902458.) After 10 seconds, grasp the specimen at the very edge (1-2 Millimeters in) of one corner with tweezers and remove from the liquid. Hold the specimen with that corner uppermost and allow excess liquid to drip for 30 seconds. Lightly dab (less than [1/2] second contact) the lower corner of the specimen on #4 filter paper (Whatman Lt., Maidstone, England) in order to remove any excess of the last partial drop. Immediately weigh the specimen, within 10 seconds, recording the weight to the nearest 0.0001 gram. The PWI for each specimen, expressed as grams of POROFIL(R) liquid per gram of fiber, is calculated as follows:

$$PWI = [\frac{(W_2 - W_1)}{W_1}] * 100\%$$

wherein

"W1" is the dry weight of the specimen, in grams; and
"W2" is the wet weight of the specimen, in grams.

[0079] The PWI for all eight individual specimens is determined as described above and the average of the eight specimens is the PWI for the sample.

[0080] The void volume ratio is calculated by dividing the PWI by 1.9 (density of fluid) to express the ratio as a percentage, whereas the void volume (gms/gm) is simply the weight increase ratio; that is, PWI divided by 100.

[0081] During fabric creping in a pressure nip, the fiber is redistributed on the fabric, making the process tolerant of less than ideal forming conditions, as are sometimes seen with a Fourdrinier former. The forming section of a Fourdrinier machine includes two major parts, the headbox and the Fourdrinier Table. The latter consists of the wire run over the various drainage-controlling devices. The actual forming occurs along the Fourdrinier Table. The hydrodynamic effects of drainage, oriented shear, and turbulence generated along the table are generally the controlling factors in the forming process. Of course, the headbox also has an important influence in the process, usually on a scale that is much larger than the structural elements of the paper web. Thus the headbox may cause such large-scale effects as variations in distribution of flow rates, velocities, and concentrations across the full width of the machine; vortex streaks generated ahead of and aligned in the machine direction by the accelerating flow in the approach to the slice; and time-varying surges or pulsations of flow to the headbox. The existence of MD-aligned vortices in headbox discharges is common. Fourdrinier formers are further described in The Sheet Forming Process, Parker, J. D., Ed., TAPPI Press (1972, reissued 1994) Atlanta, Ga.

[0082] According to the present invention, an absorbent paper web is made by dispersing papermaking fibers into aqueous furnish (slurry) and depositing the aqueous furnish onto the forming wire of a papermaking machine. Any suitable forming scheme might be used. For example, an extensive but non-exhaustive list in addition to Fourdrinier formers includes a crescent former, a C-wrap twin wire former, an S-wrap twin wire former, or a suction breast roll former. The forming fabric can be any suitable foraminous member including single layer fabrics, double layer fabrics, triple layer fabrics, photopolymer fabrics, and the like. Non-exhaustive background art in the forming fabric area includes U.S. Pat. Nos. 4,157,276; 4,605,585; 4,161,195; 3,545,705; 3,549,742; 3,858,623; 4,041,989; 4,071,050; 4,112,982; 4,149,571; 4,182,381; 4,184,519; 4,314,589; 4,359,069; 4,376,455; 4,379,735; 4,453,573; 4,564,052; 4,592,395; 4,611,639; 4,640,741; 4,709,732; 4,759,391; 4,759,976; 4,942,077; 4,967,085; 4,998,568; 5,016,678; 5,054,525; 5,066,532; 5,098,519; 5,103,874; 5,114,777; 5,167,261; 5,199,261; 5,199,467; 5,211,815; 5,219,004; 5,245,025; 5,277,761; 5,328,565; and 5,379,808. One forming fabric particularly useful with the present invention is Voith Fabrics Forming Fabric 2164 made by Voith Fabrics Corporation, Shreveport, La.

[0083] Foam-forming of the aqueous furnish on a forming wire or fabric may be employed as a means for controlling the permeability or void volume of the sheet upon fabric-creping. Foam-forming techniques are disclosed in U.S. Pat. No. 4,543,156 and Canadian Patent No. 2,053,505. The foamed fiber furnish is made up from an aqueous slurry of fibers mixed with a foamed liquid carrier just prior to its introduction to the headbox. The pulp slurry supplied to the system has a consistency in the range of from about 0.5 to about 7 weight percent fibers, preferably in the range of from about 2.5 to about 4.5 weight percent. The pulp slurry is added to a foamed liquid comprising water, air and surfactant containing 50 to 80 percent air by volume forming a foamed fiber furnish having a consistency in the range of from about 0.1 to about 3 weight percent fiber by simple mixing from natural turbulence and mixing inherent in the process elements. The addition of the pulp as a low consistency slurry results in excess foamed liquid recovered from the forming wires. The excess foamed liquid is discharged from the system and may be used elsewhere or treated for recovery of surfactant therefrom.

[0084] The furnish may contain chemical additives to alter the physical properties of the paper produced. These chemistries are well understood by the skilled artisan and may be used in any known combination. Such additives may be surface modifiers, softeners, debonders, strength aids, latexes, opacifiers, optical brighteners, dyes, pigments, sizing agents, barrier chemicals, retention aids, insolubilizers, organic or inorganic crosslinkers, or combinations thereof; said chemicals optionally comprising polyols, starches, PPG esters, PEG esters, phospholipids, surfactants, polyamines, HMCP (Hydrophobically Modified Cationic Polymers), HMAP (Hydrophobically Modified Anionic Polymers) or the like.

[0085] The pulp can be mixed with strength adjusting agents such as wet strength agents, dry strength agents and debonders/softeners and so forth. Suitable wet strength agents are known to the skilled artisan. A comprehensive but non-exhaustive list of useful strength aids include urea-formaldehyde resins, melamine formaldehyde resins, glyoxylated polyacrylamide resins, polyamide-epichlorohydrin resins and the like. Thermosetting polyacrylamides are produced by reacting acrylamide with diallyl dimethyl ammonium chloride (DADMAC) to produce a cationic polyacrylamide copolymer which is ultimately reacted with glyoxal to produce a cationic cross-linking wet strength resin, glyoxylated polyacrylamide. These materials are generally described in U.S. Pat. No. 3,556,932 to Coscia et al. and U.S. Pat. No. 3,556,933 to Williams et al.. Resins of this type are commercially available under the trade name of PAREZ 631NC by Bayer Corporation. Different mole ratios of acrylamide/-DADMAC/glyoxal can be used to produce cross-linking resins, which are useful as wet strength agents. Furthermore, other dialdehydes can be substituted for glyoxal to produce thermosetting wet strength characteristics. Of particular utility are the polyamide-epichlorohydrin wet strength resins, an example of which is sold under the trade names Kymene 557LX and Kymene 557H by Hercules Incorporated of Wilmington, Del. and Amres(R) from Georgia-Pacific Resins, Inc. These resins and the process for making the resins are described in U.S. Pat. No. 3,700,623 and U.S. Pat. No. 3,772,076. An extensive description of polymeric-epihalohydrin resins is given in Chapter 2: Alkaline-Curing Polymeric Amine-Epichlorohydrin by Espy in Wet Strength Resins and Their Application (L. Chan, Editor, 1994). A reasonably comprehensive list of wet strength resins is described by Westfelt in Cellulose Chemistry and Technology Volume 13, p. 813, 1979, which is incorporated herein by reference.

[0086] Suitable temporary wet strength agents may likewise be included. A comprehensive but non-exhaustive list of useful temporary wet strength agents includes aliphatic and aromatic aldehydes including glyoxal, malonic dialdehyde, succinic dialdehyde, glutaraldehyde and dialdehyde starches, as well as substituted or reacted starches, disaccharides, polysaccharides, chitosan, or other reacted polymeric reaction products of monomers or polymers having aldehyde groups, and optionally, nitrogen groups. Representative nitrogen containing polymers, which can suitably be reacted with the aldehyde containing monomers or polymers, includes vinyl-amides, acrylamides and related nitrogen containing polymers. These polymers impart a positive charge to the aldehyde containing reaction product. In addition, other commercially available temporary wet strength agents, such as, PAREZ 745, manufactured by Bayer can be used, along with those disclosed, for example in U.S. Pat. No. 4,605,702.

[0087] The temporary wet strength resin may be any one of a variety of water-soluble organic polymers comprising aldehydic units and cationic units used to increase dry and wet tensile strength of a paper product. Such resins are described in U.S. Pat. Nos. 4,675,394; 5,240,562; 5,138,002; 5,085,736; 4,981,557; 5,008,344; 4,603,176; 4,983,748; 4,866,151; 4,804,769 and 5,217,576. Modified starches sold under the trademarks CO-BOND(R) 1000 and CO-BOND(R) 1000 Plus, by National Starch and Chemical Company of Bridgewater, N.J. may be used. Prior to use, the cationic aldehydic water soluble polymer can be prepared by preheating an aqueous slurry of approximately 5% solids maintained at a temperature of approximately 115.6° C (240 degrees Fahrenheit) and a pH of about 2.7 for approximately 3.5 minutes. Finally, the slurry can be quenched and diluted by adding water to produce a mixture of approximately 1.0% solids at less than about 54.4° C (130 degrees Fahrenheit).

[0088] Other temporary wet strength agents, also available from National Starch and Chemical Company are sold under the trademarks CO-BOND(R) 1600 and CO-BOND(R) 2300. These starches are supplied as aqueous colloidal dispersions and do not require preheating prior to use.

[0089] Temporary wet strength agents such as glyoxylated polyacrylamide can be used. Temporary wet strength agents such glyoxylated polyacrylamide resins are produced by reacting acrylamide with diallyl dimethyl ammonium chloride (DADMAC) to produce a cationic polyacrylamide copolymer which is ultimately reacted with glyoxal to produce a cationic cross-linking temporary or semi-permanent wet strength resin, glyoxylated polyacrylamide. These materials are generally described in U.S. Pat. No. 3,556,932 to Coscia et al. and U.S. Pat. No. 3,556,933 to Williams et al.. Resins of this type are commercially available under the trade name of PAREZ 631 NC, by Bayer Industries. Different mole ratios of acrylamide/DADMAC/glyoxal can be used to produce cross-linking resins, which are useful as wet strength agents. Furthermore, other dialdehydes can be substituted for glyoxal to produce wet strength characteristics.

[0090] Suitable dry strength agents include starch, guar gum, polyacrylamides, carboxymethyl cellulose and the like. Of particular utility is carboxymethyl cellulose, an example of which is sold under the trade name Hercules CMC, by Hercules Incorporated of Wilmington, Del. According to one embodiment, the pulp may contain from about 0 kg/ton to about 6.8 kg/ton (about 0 to about 15 lb/ton) of dry strength agent. According to another embodiment, the pulp may contain from about 0.45 to about 2.27 kg/ton (about 1 to about 5 lbs/ton) of dry strength agent.

[0091] Suitable debonders are likewise known to the skilled artisan. Debonders or softeners may also be incorporated into the pulp or sprayed upon the web after its formation. The present invention may also be used with softener materials including but not limited to the class of amido amine salts derived from partially acid neutralized amines. Such materials are disclosed in U.S. Pat. No. 4,720,383. Evans, Chemistry and Industry, 5 Jul. 1969, pp. 893-903; Egan, J. Am. Oil Chemist's Soc., Vol. 55 (1978), pp. 118-121; and Trivedi et al., J. Am. Oil Chemist's Soc., June 1981, pp. 754-756, indicate that softeners are often available commercially only as complex mixtures rather than as single compounds. While the following discussion will focus on the predominant species, it should be understood that commercially available mixtures would generally be used in practice.

[0092] Quasoft 202-JR is a suitable softener material, which may be derived by alkylating a condensation product of oleic acid and diethylenetriamine. Synthesis conditions using a deficiency of alkylation agent (e.g., diethyl sulfate) and only one alkylating step, followed by pH adjustment to protonate the non-ethylated species, result in a mixture consisting of cationic ethylated and cationic non-ethylated species. A minor proportion (e.g., about 10%) of the resulting amido amine cyclize to imidazoline compounds. Since only the imidazoline portions of these materials are quaternary ammonium compounds, the compositions as a whole are pH-sensitive. Therefore, in the practice of the present invention with this class of chemicals, the pH in the head box should be approximately 6 to 8, more preferably 6 to 7 and most preferably 6.5 to 7.

[0093] Quaternary ammonium compounds, such as dialkyl dimethyl quaternary ammonium salts are also suitable particularly when the alkyl groups contain from about 10 to 24 carbon atoms. These compounds have the advantage of being relatively insensitive to pH.

[0094] Biodegradable softeners can be utilized. Representative biodegradable cationic softeners/debonders are disclosed in U.S. Pat. Nos. 5,312,522; 5,415,737; 5,262,007; 5,264,082; and 5,223,096. The compounds are biodegradable diesters of quaternary ammonia compounds, quaternized amine-esters, and biodegradable vegetable oil based esters functional with quaternary ammonium chloride and diester dierucyldimethyl ammonium chloride and are representative biodegradable softeners.

[0095] In some embodiments, a particularly preferred debonder composition includes a quaternary amine component as well as a nonionic surfactant.

[0096] The nascent web is typically dewatered on a papermaking felt. Any suitable felt may be used. For example, felts can have double-layer base weaves, triple-layer base weaves, or laminated base weaves. Preferred felts are those having the laminated base weave design. A wet-press-felt which may be particularly useful with the present invention is Vector 3 made by Voith Fabric. Background art in the press felt area includes U.S. Pat. Nos. 5,657,797; 5,368,696; 4,973,512; 5,023,132; 5,225,269; 5,182,164; 5,372,876; and 5,618,612. A differential pressing felt as is disclosed in U.S. Pat. No. 4,533,437 to Curran et al. may likewise be utilized.

[0097] Suitable creping fabrics include single layer, multi-layer, or composite preferably open meshed structures. Fabrics may have at least one of the following characteristics: (1) on the side of the creping fabric that is in contact with the wet web (the "top" side), the number of machine direction (MD) strands per 2.54 cm (1 inch) (mesh) is from 10 to 200 and the number of cross-direction (CD) strands per 2.54 cm (1 inch) (count) is also from 10 to 200; (2) The strand diameter is typically smaller than 1.27 mm (0.050 inch); (3) on the top side, the distance between the highest point of the MD knuckles and the highest point on the CD knuckles is from about 0.0254 mm (0.001 inch) to about 0.508 or 0.762 mm (0.02 or 0.03 inch); (4) In between these two levels there can be knuckles formed either by MD or CD strands that give the topography a three dimensional hill/valley appearance which is imparted to the sheet; (5) The fabric may be oriented in any suitable way so as to achieve the desired effect on processing and on properties in the product; the long warp knuckles may be on the top side to increase MD ridges in the product, or the long shute knuckles may be on the top side if more CD ridges are desired to influence creping characteristics as the web is transferred from the transfer cylinder to the creping fabric; and (6) the fabric may be made to show certain geometric patterns that are pleasing to the eye, which is typically repeated between every two to 50 warp yarns. Suitable commercially available coarse fabrics include a number of fabrics made by Voith Fabrics.

[0098] The creping fabric may thus be of the class described in U.S. Pat. No. 5,607,551 to Farrington et al, Cols. 7-8 thereof, as well as the fabrics described in U.S. Pat. No. 4,239,065 to Trokhan and U.S. Pat. No. 3,974,025 to Ayers. Such fabrics may have about 20 to about 60 filaments per 2.54 cm (1 inch) and are formed from monofilament polymeric fibers having diameters typically ranging from about 0.2032 mm to about 0.635 mm (0.008 to about 0.025 inches). Both warp and weft monofilaments may, but need not necessarily be of the same diameter.

[0099] In some cases the filaments are so woven and complimentarily serpentinely configured in at least the Z-direction (the thickness of the fabric) to provide a first grouping or array of coplanar top-surface-plane crossovers of both sets of filaments; and a predetermined second grouping or array of sub-top-surface crossovers. The arrays are interspersed so that portions of the top-surface-plane crossovers define an array of wicker-basket-like cavities in the top surface of the fabric which cavities are disposed in staggered relation in both the machine direction (MD) and the cross-machine direction (CD), and so that each cavity spans at least one sub-top-surface crossover. The cavities are discretely perimetrically enclosed in the plan view by a picket-like-lineament comprising portions of a plurality of the top-surface plane crossovers. The loop of fabric may comprise heat set monofilaments of thermoplastic material; the top surfaces of the coplanar top-surface-plane crossovers may be monoplanar flat surfaces. Specific embodiments of the invention include satin weaves as well as hybrid weaves of three or greater sheds, and mesh counts of from about (10x10 to about 120x120 filaments per inch) about 4x4 to about 47x47 per centimeter, although the preferred range of mesh counts is from (about 18 by 16 to about 55 by 48 filaments per inch) about 9x8 to about 22x19 per centimeter.

[0100] Instead of an impression fabric, a dryer fabric may be used as the creping fabric if so desired. Suitable fabrics are described in U.S. Pat. No. 5,449,026 (woven style) and U.S. Pat. No. 5,690,149 (stacked MD tape yarn style) to Lee as well as U.S. Pat. No. 4,490,925 to Smith (spiral style).

[0101] If a Fourdrinier former or other gap former is used, the nascent web may be conditioned with vacuum boxes and a steam shroud until it reaches a solids content suitable for transferring to a dewatering felt. The nascent web may be transferred with vacuum assistance to the felt. In a crescent former, use of vacuum assist is unnecessary as the nascent web is formed between the forming fabric and the felt.

[0102] Can drying can be used alone or in combination with impingement air drying, the combination being especially convenient if a two tier drying section layout is available as hereinafter described. Impingement air drying may also be used as the only means of drying the web as it is held in the fabric if so desired or either may be used in combination with can dryers. Suitable rotary impingement air drying equipment is described in U.S. Pat. No. 6,432,267 to Watson and U.S. Pat. No. 6,447,640 to Watson et al. Inasmuch as the process of the invention can readily be practiced on existing equipment with reasonable modifications, any existing flat dryers can be advantageously employed so as to conserve capital as well.

[0103] Alternatively, the web may be through-dried after fabric creping as is well known in the art. Representative references include: U.S. Pat. No. 3,342,936 to Cole et al; U.S. Pat. No. 3,994,771 to Morgan, Jr. et al.; U.S. Pat. No. 4,102,737 to Morton; and U.S. Pat. No. 4,529,480 to Trokhan.

[0104] Turning to the Figures, FIG. 1 shows a cross-section (120X) along the MD of a fabric-creped, undrawn sheet 10 illustrating a fiber-enriched region 12. It will be appreciated that fibers of the fiber-enriched region 12 have orientation biased in the CD, especially at the right side of region 12, where the web contacts a knuckle of the creping fabric.

[0105] FIG. 2 illustrates sheet 10 drawn 45% after fabric creping and drying. Here it is seen regions 12 are attenuated or dispersed in the machine direction when the microfolds of regions 12 expand or unfold. The drawn web exhibits increased bulk and void volume with respect to an undrawn web. Structural and property changes are further appreciated by reference to FIGS. 3-12.

[0106] FIG. 3 is a photomicrograph (10X) of the fabric side of a fabric-creped web of the invention which was prepared without substantial subsequent draw of the web. It is seen in FIG. 3 that sheet 10 has a plurality of very pronounced high basis weight, fiber-enriched regions 12 having fiber with orientation biased in the cross-machine direction (CD) linked by relatively low basis weight regions 14. It is appreciated from the photographs that linking regions 14 have fiber orientation bias extending along a direction between fiber enriched regions 12. Moreover, it is seen that the fold lines or creases of the microfolds of fiber enriched regions 12 extend along the CD.

[0107] FIG. 4 is a photomicrograph (10X) of the fabric side of a fabric-creped web of the invention which was fabric creped, dried and subsequently drawn 45%. It is seen in FIG. 4 that sheet 10 still has a plurality of relatively high basis weight regions 12 linked by lower basis regions 14; however, the fiber-enriched regions 12 are much less pronounced after the web is drawn as will be appreciated by comparing FIGS. 3 and 4.

[0108] FIG. 5 is a photomicrograph (10X) of the dryer side of the web of FIG. 3, that is, the side of the web opposite the creping fabric. This web was fabric creped and dried without drawing. Here, there are seen fiber-enriched regions 12 of relatively high basis weights as well as lower basis weight regions 14 linking the fiber-enriched regions. These features are generally less pronounced on the dryer or "can" side of the web; except however, the attenuation or unfolding of the fiber-enriched regions is perhaps more readily observed on the dryer side of the web when the fabric-creped web 10 is drawn as is seen in FIG. 6.

[0109] FIG. 6 is a photomicrograph (10X) of the dryer side of a fabric-creped web 10 prepared in accordance with the invention which was fabric creped, dried and subsequently drawn 45%. Here it is seen that fiber-enriched high basis weight regions 12 "open" or unfold somewhat as they attenuate (as is also seen in FIGS. 1 and 2 at higher magnification). The lower basis weight regions 14 remain relatively intact as the web is drawn. In other words, the fiber-enriched regions are preferentially attenuated as the web is drawn. It is further seen in FIG. 6 that the relatively compressed fiber-enriched regions 12 have been expanded in the sheet.

[0110] Without intending to be bound by any theory, it is believed that fabric-creping the web as described herein produces a cohesive fiber reticulum having pronounced variation in local basis weight. The network can be substantially preserved while the web is dried, for example, such that dry-drawing the web will disperse or attenuate the fiber-enriched regions somewhat and increase the void volume of the web. This attribute of the invention is manifested in FIG. 6 by microfolds in the web at regions 12 opening upon drawing of the web to greater length. In FIG. 5, corresponding regions 12 of the undrawn web remain closed.

[0111] The invention process and preferred products thereof are further appreciated by reference to FIGS. 7 through 24. FIG. 7 is a photomicrograph of a very low basis weight, open mesh web 20 having a plurality of relatively high basis weight pileated regions 22 interconnected by a plurality of lower basis weight linking regions 24. The cellulosic fibers of linking regions 24 have orientation which is biased along the direction as to which they extend between pileated regions 22, as is perhaps best seen in the enlarged view of FIG. 8. The orientation and variation in local basis weight is surprising in view of the fact that the nascent web has an apparently random fiber orientation when formed and is transferred largely undisturbed to a transfer surface prior to being wet-creped therefrom. The imparted ordered structure is distinctly seen at extremely low basis weights where web 20 has open portions 26 and is thus an open mesh structure.

[0112] FIG. 9 shows a web together with the creping fabric 28 upon which the fibers were redistributed in a wet-creping nip after generally random formation to a consistency of 40-50 percent or so prior to creping from the transfer cylinder.

[0113] While the structure including the pileated and reoriented regions is easily observed in open meshed embodiments of very low basis weight, the ordered structure of the products of the invention is likewise seen when basis weight is increased where integument regions of fiber 30 span the pileated and linking regions as is seen in FIGS. 10 through 12 so that a sheet 32 is provided with substantially continuous surfaces as is seen particularly in FIGS. 19 and 22, where the darker regions are lower in basis weight while the almost solid white regions are relatively compressed fiber.

[0114] The impact of processing variables and so forth are also appreciated from FIGS. 10 through 12. FIGS. 10 and 11 both show 8.62 kg (19 lb) sheet; however, the pattern in terms of variation in basis weight is more prominent in FIG. 11 because the Fabric Crepe was much higher (40% vs. 17%). Likewise, FIG. 12 shows a higher basis weight web

12.25 kg (27 lb) at 28% crepe where the pileated, linking and integument regions are all prominent.

[0115] Redistribution of fibers from a generally random arrangement into a patterned distribution including orientation bias as well as fiber-enriched regions corresponding to the creping fabric structure is still further appreciated by reference to FIGS. 13 through 24.

[0116] FIG. 13 is a photomicrograph (10X) showing a cellulosic web from which a series of samples were prepared and scanning electron micrographs (SEMs) made to further show the fiber structure. On the left of FIG. 13 there is shown a surface area from which the SEM surface images 14, 15 and 16 were prepared. It is seen in these SEMs that the fibers of the linking regions have orientation biased along their direction between pileated regions as was noted earlier in connection with the photomicrographs. It is further seen in FIGS. 14, 15 and 16 that the integument regions formed have a fiber orientation along the machine direction. The feature is illustrated rather strikingly in FIGS. 17 and 18.

[0117] FIGS. 17 and 18 are views along line XS-A of FIG. 13, in section. It is seen especially at 200 magnification (FIG. 18) that the fibers are oriented toward the viewing plane, or machine direction, inasmuch as the majority of the fibers were cut when the sample was sectioned.

[0118] FIGS. 19 and 20, a section along line XS-B of the sample of FIG. 13, shows fewer cut fibers especially at the middle portions of the photomicrographs, again showing an MD orientation bias in these areas. Note in FIG. 19, U-shaped folds are seen in the fiber-enriched area to the left.

[0119] FIGS. 21 and 22 are SEMs of a section of the sample of FIG. 13 along line XS-C. It is seen in these Figures that the pileated regions (left side) are "stacked up" to a higher local basis weight. Moreover, it is seen in the SEM of FIG. 22 that a large number of fibers have been cut in the pileated region (left) showing reorientation of the fibers in this area in a direction transverse to the MD, in this case along the CD. Also noteworthy is that the number of fiber ends observed diminishes as one moves from left to right, indicating orientation toward the MD as one moves away from the pileated regions.

[0120] FIGS. 23 and 24 are SEMs of a section taken along line XS-D of FIG. 13. Here it is seen that fiber orientation bias changes as one moves across the CD. On the left, in a linking or colligating region, a large number of "ends" are seen indicating MD bias. In the middle, there are fewer ends as the edge of a pileated region is traversed, indicating more CD bias until another linking region is approached and cut fibers again become more plentiful, again indicating increased MD bias.

[0121] The desired redistribution of fiber is achieved by an appropriate selection of consistency, fabric or fabric pattern, nip parameters, and velocity delta, the difference in speed between the transfer surface and creping fabric. Velocity deltas of at least 1.83 km/h (100 fpm), 3.66 km/h (200 fpm), 9.14 km/h (500 fpm), 18.29 km/h (1000 fpm), 27.43 km/h (1500 fpm) or even in excess of 36.58 km/h (2000 fpm) may be needed under some conditions to achieve the desired redistribution of fiber and combination of properties as will become apparent from the discussion which follows. In many cases, velocity deltas of from about 9.14 km/h (500 fpm) to about 36.58 km/h (2000 fpm) will suffice. Forming of the nascent web, for example, control of a headbox jet and forming wire or fabric speed is likewise important in order to achieve the desired properties of the product, especially MD/CD tensile ratio. Likewise, drying may be carried out while the preserving the drawable reticulum of the web especially if it is desired to increase bulk substantially by drawing the web. It is seen in the discussion which follows that the following salient parameters are selected or controlled in order to achieve a desired set of characteristics in the product: consistency at a particular point in the process (especially at fabric crepe); fabric pattern; fabric creping nip parameters; fabric crepe ratio; velocity deltas, especially transfer surface/creping fabric and headbox jet/forming wire; and post fabric-crepe handling of the web. The products of the invention are compared with conventional products in Table 2 below.

Table 2 - Comparison of Typical Web Properties

Property	Conventional Wet Press	Conventional Throughdried	High Speed Fabric Crepe
SAT g/g	4	10	6-9
*Caliper	40	120+	50-115
MD/CD Tensile	>1	>1	<1
CD Stretch (%)	3-4	7-15	5-15
*mils/8sheet			

[0122] FIG. 25 is a schematic diagram of a papermachine 40 having a conventional twin wire forming section 42, a felt run 44, a shoe press section 46 a creping fabric 48 and a Yankee dryer 50 suitable for practicing the present invention. Forming section 42 includes a pair of forming fabrics 52, 54 supported by a plurality of rolls 56, 58, 60, 62, 64, 66 and a forming roll 68. A headbox 70 provides papermaking furnish issuing therefrom as a jet in the machine direction to a nip 72 between forming roll 68 and roll 56 and the fabrics. The furnish forms a nascent web 74 which is dewatered on the fabrics with the assistance of vacuum, for example, by way of vacuum box 76.

[0123] The nascent web is advanced to a papermaking felt 78 which is supported by a plurality of rolls 80, 82, 84, 85 and the felt is in contact with a shoe press roll 86. The web is of low consistency as it is transferred to the felt. Transfer may be assisted by vacuum; for example roll 80 may be a vacuum roll if so desired or a pickup or vacuum shoe as is known in the art. As the web reaches the shoe press roll it may have a consistency of 10-25 percent, preferably 20 to 25 percent or so as it enters nip 88 between shoe press roll 86 and transfer roll 90. Transfer roll 90 may be a heated roll if so desired. Instead of a shoe press roll, roll 86 could be a conventional suction pressure roll. If a shoe press is employed, it is desirable and preferred that roll 84 is a vacuum roll effective to remove water from the felt prior to the felt entering the shoe press nip since water from the furnish will be pressed into the felt in the shoe press nip. In any case, using a vacuum roll at 84 is typically desirable to ensure the web remains in contact with the felt during the direction change as one of skill in the art will appreciate from the diagram.

[0124] Web 74 is wet-pressed on the felt in nip 88 with the assistance of pressure shoe 92. The web is thus compactively dewatered at 88, typically by increasing the consistency by 15 or more points at this stage of the process. The configuration shown at 88 is generally termed a shoe press; in connection with the present invention, cylinder 90 is operative as a transfer cylinder which operates to convey web 74 at high speed, typically 18.29 km/h -109.73 km/h (1000 fpm-6000 fpm), to the creping fabric.

[0125] Cylinder 90 has a smooth surface 94 which may be provided with adhesive and/or release agents if needed. Web 74 is adhered to transfer surface 94 of cylinder 90 which is rotating at a high angular velocity as the web continues to advance in the machine-direction indicated by arrows 96. On the cylinder, web 74 has a generally random apparent distribution of fiber.

[0126] Direction 96 is referred to as the machine-direction (MD) of the web as well as that of papermachine 40; whereas the cross-machine-direction (CD) is the direction in the plane of the web perpendicular to the MD.

[0127] Web 74 enters nip 88 typically at consistencies of 10-25 percent or so and is dewatered and dried to consistencies of from about 25 to about 70 by the time it is transferred to creping fabric 48 as shown in the diagram.

[0128] Fabric 48 is supported on a plurality of rolls 98, 100, 102 and a press nip roll 104 and forms a fabric crepe nip 106 with transfer cylinder 90 as shown.

[0129] The creping fabric defines a creping nip over the distance in which creping fabric 48 is adapted to contact roll 90; that is, applies significant pressure to the web against the transfer cylinder. To this end, backing (or creping) roll 100 may be provided with a soft deformable surface which will increase the length of the creping nip and increase the fabric creping angle between the fabric and the sheet and the point of contact or a shoe press roll could be used as roll 100 to increase effective contact with the web in high impact fabric creping nip 106 where web 74 is transferred to fabric 48 and advanced in the machine-direction. By using different equipment at the creping nip, it is possible to adjust the fabric creping angle or the takeaway angle from the creping nip. Thus, it is possible to influence the nature and amount of redistribution of fiber, delamination / debonding which may occur at fabric creping nip 106by adjusting these nip parameters. In some embodiments, it may by desirable to restructure the z-direction interfiber characteristics; while in other cases, it may be desired to influence properties only in the plane of the web. The creping nip parameters can influence the distribution of fiber in the web in a variety of directions, including inducing changes in the z-direction as well as the MD and CD. In any case, the transfer from the transfer cylinder to the creping fabric is high impact in that the fabric is traveling slower than the web and a significant velocity change occurs. Typically, the web is fabric creped anywhere from 10-60 percent and higher (200-300%) during transfer from the transfer cylinder to the fabric.

[0130] Creping nip 106 generally extends over a fabric creping nip distance of anywhere from about 3.18 mm (1/8") to about 5.08 cm (2"), typically 1.27 cm to 5.08 cm (1/2" to 2"). For a creping fabric with 32 CD strands per 2.54 cm (1 inch), web 74 thus will encounter anywhere from about 4 to 64 weft filaments in the nip.

[0131] The nip pressure in nip 106, that is, the loading between backing roll 100 and transfer roll 90 is suitably 3502 N/m - 35020 N/m (20-200 PLI), preferably 7500 N/m - 12259 N/m (40-70 pounds per linear inch (PLI)).

[0132] After fabric creping, the web continues to advance along MD 96 where it is wet-pressed onto Yankee cylinder 110 in transfer nip 112. Transfer at nip 112 occurs at a web consistency of generally from about 25 to about 70 percent. At these consistencies, it is difficult to adhere the web to surface 114 of cylinder 110 firmly enough to remove the web from the fabric thoroughly. This aspect of the process is important, particularly when it is desired to use a high velocity drying hood as well as maintain high impact creping conditions.

[0133] In this connection, it is noted that conventional TAD processes do not employ high velocity hoods since sufficient adhesion to the Yankee is not achieved.

[0134] It has been found in accordance with the present invention that the use of particular adhesives cooperate with a moderately moist web (25-70 percent consistency) to adhere it to the Yankee sufficiently to allow for high velocity operation of the system and high jet velocity impingement air drying. In this connection, a poly(vinyl alcohol)/polyamide adhesive composition as noted above is applied at 116 as needed.

[0135] The web is dried on Yankee cylinder 110 which is a heated cylinder and by high jet velocity impingement air in Yankee hood 118. As the cylinder rotates, web 74 is creped from the cylinder by creping doctor 119 and wound on a take-up roll 120. Creping of the paper from a Yankee dryer may be carried out using an undulatory creping blade, such as that disclosed in U.S. Pat. No. 5,690,788. Use of the undulatory crepe blade has been shown to impart several advantages when used in production of tissue products. In general, tissue products creped using an undulatory blade have higher caliper (thickness), increased CD stretch, and a higher void volume than do comparable tissue products produced using conventional crepe blades. All of these changes effected by use of the undulatory blade tend to correlate with improved softness perception of the tissue products.

[0136] When a wet-crepe process is employed, an impingement air dryer, a through-air dryer, or a plurality of can dryers can be used instead of a Yankee. Impingement air dryers are disclosed in the following patents and applications:

U.S. Pat. No. 5,865,955 of Ilvespaaet et al.

U.S. Pat. No. 5,968,590 of Ahonen et al.

U.S. Pat. No. 6,001,421 of Ahonen et al.

U.S. Pat. No. 6,119,362 of Sundqvist et al.

U.S. patent application Ser. No. 09/733,172, entitled Wet Crepe, Impingement-Air Dry Process for Making Absorbent Sheet, now U.S. Pat. No. 6,432,267.

[0137] A throughdrying unit as is well known in the art and described in U.S. Pat. No. 3,432,936 to Cole et al., as is U.S. Pat. No. 5,851,353 which discloses a can-drying system.

[0138] There is shown in FIG. 26 a preferred papermachine 40 for use in connection with the present invention. Papermachine 40 is a three fabric loop machine having a forming section 42 generally referred to in the art as a crescent former. Forming section 42 includes a forming wire 52 supported by a plurality of rolls such as rolls 62, 65. The forming section also includes a forming roll 68 which supports paper making felt 78 such that web 74 is formed directly on felt 78. Felt run 44 extends to a shoe press section 46 wherein the moist web is deposited on a transfer roll 90 as described above. Thereafter web 74 is creped onto fabric in fabric crepe nip between rolls 90, 100 before being deposited on Yankee dryer in another press nip 112. Vacuum is optionally applied by vacuum box 75 as the web is held in fabric. Headbox 70 and press shoe 92 operate as noted above in connection with FIG. 25. The system includes a vacuum turning roll 84, in some embodiments; however, the three loop system may be configured in a variety of ways wherein a turning roll is not necessary. This feature is particularly important in connection with the rebuild of a papermachine inasmuch as the expense of relocating associated equipment i.e. pulping or fiber processing equipment and/or the large and expensive drying equipment such as the Yankee dryer or plurality of can dryers would make a rebuild prohibitively expensive unless the improvements could be configured to be compatible with the existing facility.

[0139] There is shown schematically in FIG. 27 a portion of a paper machine 200. Paper machine 200 is provided with a forming and fabric creping section as described above wherein a web 205 is fabric-creped onto a creping fabric 202. Web 205 is transferred from the creping fabric to a Yankee dryer 206. Rather than being creped from the Yankee dryer the web is transferred off the dryer at sheet control roll 210. The web is then fed to a pair of draw rolls 212, 214, as described in more detail hereinafter. There is optionally provided a calendering station 216 having a pair of calender rolls 218, 220. Web 205 is thus calendered on line before being wound onto reel 224 over guide roll 222.

[0140] In order to achieve the advantages of the invention, it is believed that high fabric crepe ratios should be practiced at the creping section. The sheet so made may then be attached to a Yankee dryer as shown generally in FIG. 27, but with a special adhesion system explained in more detail hereinafter. The sheet is preferably dried to the desired dryness on the Yankee cylinder. Instead of creping the sheet off the cylinder, a relatively small diameter control roll 210 is located very close to, and optionally touching, the Yankee dryer. This relatively smaller diameter roll controls the sheet pull off angle so that the sheet does not dance up and down on the dryer surface. The smaller the diameter, the sharper the take off angle and the sharper the take off angle, the less tension is required in the machine direction of the sheet to break the adhesion of web 205 to Yankee 206. The sheet may subsequently be taken through a pull out section where a major portion of the fabric crepe provided to the web in the creping section is removed from the sheet. This stretching or drawing of the web opens up the piles of fiber that tend to build up ahead of the creping knuckle, thereby improving the absorptive properties of the sheet as well as the tactile properties. The sheet or web can then be calendered to reduce two sidedness and maintain the desired caliper properties. As shown in FIG. 27, calendering is preferably done on line.

[0141] It will be appreciated by those of skill in the art that the overall process is exceedingly efficient as the wet end may be run very fast as compared with the Yankee dryer and the reel can also be run considerably faster than the Yankee. The slow Yankee dryer speeds means that more efficient drying of heavy weight sheets can be readily achieved with the apparatus of the present invention. Referring to FIGS. 28a and 28b there is shown schematically a preferred adhesive system for use with the present invention. FIG. 28a is a schematic profile of a Yankee dryer such as Yankee 206 wherein there is provided an adhesive layer 230 under web 205. FIG. 28b is an enlarged view showing the various layers of FIG. 28a. The Yankee dryer surface is indicated at 232 while the web is indicated at 205. Adhesive layer 230 includes soft adhesive 234 as well as a dryer protection layer 236.

[0142] For the process of the invention to be operated in preferred embodiments, the dryer coating should have the following characteristics.

[0143] Because the sheet has been embedded into the creping fabric at the creping fabric step, the adhesive needs to exhibit considerable wet tack properties in order to effectively transfer the web from the creping fabric to the Yankee dryer. For this reason the creping process of the present invention generally requires an adhesive with high wet tact such as PVOH to be used in the adhesive mix. However, PVOH while exhibiting high wet tact also exhibits very high dry adhesion levels requiring the use of a creping blade to remove the dried sheet from the dryer surface. For the process of FIG. 27 to run, the sheet must be drawn off the dryer surface without excessively pulling the stretch out of the sheet, destroying the integrity of the web or breaking the sheet at defects points. Therefore, this adhesive level, described as soft adhesive must be aggressive in tacking the wet sheet to the dryer surface, strong enough in holding the sheet to the dryer under the influence of high velocity drying hoods but at the removal point the adhesive must exhibit sufficient release characteristics so the desired sheet properties are preserved. That is to say, the nature of the drawable fiber reticulum should be preserved. It is believed that the adhesive must exhibit: high wet tack and low dry adhesion to the sheet; cohesive internal strength much greater than the dried paper adhesion strength so that bits of adhesive do not leave with the sheet; and very high dry adhesion to the dryer surface. The dryer protection layer should have very high dry adhesion to the dryer surface. In normal operations, a creping blade is required to start the sheet in the winding process before it can be pulled off the dryer surface. During this time care must be taken to prevent the blade from damaging the dryer surface or removing the adhesive coating. This can be accomplished with the nature of these coating materials by using a soft, non-metallic creping blade for sheet starting. The dryer protection layer is applied and cured prior to the dryer being used to dry paper. This layer can be applied after a dryer grind or after thoroughly cleaning the old coatings off the dryer surface. This coating is usually a polyamide based, cross linkable material that is applied and then cured with heat prior to start up.

[0144] There is shown in FIGS. 29a and 29b a schematic diagram showing the starting and operating configuration of draw rolls 212 and 214. The draw rolls are mounted on moveable axles at 240 and 242 respectively. During start up rolls 212 and 214 are generally disposed in opposing relationship on either side of web 205. The configuration shown is particularly convenient for threading web 205. Once threaded, the rolls are rotated upwards of 270° so that the sheet will wrap around the two rolls sufficiently so the sheet can be gripped and pulled out by each of the driven rolls. The operational configuration is shown in FIG. 29b where the rolls run at speeds that are above the speeds of Yankee. Roll 214 is run at speeds slightly faster than the Yankee dryer so that the sheet can be pulled off the Yankee and the stretching process begun. Roll 212 will run considerably faster than roll 214. Downstream of this stretch section there may be further provided calender stations where the remaining pull out will occur between the calender rolls and roll 212. It is preferable that all of the rolls are located as closely as is practical to minimize open sheet draws as the web progresses in the machine direction.

[0145] Further refinement will be readily appreciated by those of skill in the art. For example there is shown in FIG. 30 a paper machine 300 substantially the same as paper machine 200 additionally provided with an embossing roll 315 provided to emboss the web shortly after it is applied to the Yankee dryer.

[0146] That is to say, there is shown in FIG. 30, a paper machine 300 including a conventional forming section, a fabric creping section (not shown) which includes a creping fabric 302 which carries a web 305 to a Yankee dryer 306. Web 305 is transferred to the surface of Yankee dryer 306 and shortly thereafter embossed with an embossing roll 315 as web 305 is dried. In some cases when it is desired to peel the web from the Yankee, it may be preferred to run the embossing roll and the dryer surface at a slight speed differential. Preferably the Yankee 306 is provided with an adhesive system having a Yankee protection layer and a soft layer as noted above. The web is dried on the Yankee and removed at control roll 310. The web is drawn or stretched by draw rolls 312, 314, and then calendered at 316 prior to being rolled up on reel 324.

EXAMPLES 1-8 AND EXAMPLES A-F

[0147] A series of absorbent sheets were prepared with different amounts of fabric crepe and overall crepe. In general, a 50/50 southern softwood kraft/southern hardwood kraft furnish was used with a 36 m (M weave with the CD knuckles to the sheet). Chemicals such as debonders and strength resins were not used. The fabric crepe ratio was about 1.6. The sheet was fabric creped at about 50% consistency using a line force of about 4378 N/m (25 pli) against the backing roll; thereafter the sheet was dried in the fabric by bringing it into contact with heated dryer cans, removed from the fabric and wound onto the reel of the papermachine. Data from these trials are designated as Examples 1-8 in Table 3 where post-fabric creping draw is also specified.

[0148] Further trials were made with an apparatus using compactive dewatering, fabric creping and Yankee drying (instead of can drying) using an apparatus of the class shown in FIGS. 25 and 26 wherein the web was adhered to the Yankee cylinder with a polyvinyl alcohol containing adhesive and removed by blade creping. Data from these trials appears in Table 3 as Examples A-F.

Table 3 - Sheet Properties Examples 1-8; A-F

Sample	Description	VV	Fabric Fric 1	Fabric Fric 2	Opp. Fric 1	Opp. Fric 2	Fric Ratio1	Fric Ratio2	Percent Draw	Basis Weight	Caliper 1 Sheet, 0.001 in	Calc'd Bulk, cc/gram
1	Control	5.15	2.379	2.266			2.16	2.74	0	19.6	11.5	9.1
2	15% Draw	5.33	1.402	1.542			1.15	1.53	15	20.1	12.0	9.3
3	30% Draw	5.45	2.016	1.662			1.83	1.27	30	18.4	11.7	9.9
4	45% Draw	6.32	1.843	1.784			1.02	1.78	45	15.3	10.2	10.4
5	Control				1.100	0.828			0			
6	15% Draw				1.216	1.011			15			
7	30% Draw				1.099	1.304			30			
8	45% Draw				1.815	1.002			45			
A	Control	5.727	1.904	1.730			2.13	1.68	0	21.6	14.2	10.3
B	10% Draw	5.013	2.093	2.003			1.56	1.48	10	20.0	13.2	10.3
C	17% Draw	4.771	0.846	0.818			0.76	0.84	17	19.1	11.4	93
D	Control				0.895	1.029			0		14.2	
B	10% Draw				1.345	1.356			10		12.7	
F	17% Draw				1.107	0.971			17		11.5	

[0149] Without intending to be bound by any theory, it is believed that if the cohesiveness of the fabric-creped, drawable reticulum of the web is preserved during drying, then drawing the web will unfold or otherwise attenuate the fiber-enriched regions of the web to increase absorbency. In Table 4 it is seen that conventional wet press (CWP) and thoroughdried products (TAD) exhibit much less property change upon drawing than fabric creped/can-dried absorbent sheet of the invention. These results are discussed further below together with additional examples.

[0150] Following generally the procedures noted above, additional runs were made with in-fabric (can) dried and Yankee-dried basesheet. The Yankee-dried material was adhered to a Yankee dryer with a polyvinyl alcohol adhesive and blade-creped. The Yankee-dried material generally exhibits less property change upon drawing (until most of the stretch is pulled out) than did the can-dried material. This may be altered with less aggressive blade creping so that the product behaves more like the can-dried product. Test data is summarized in Tables 5 through 12 and FIGS. 31 through 39. Fabrics tested included 44G, 44M and 36M oriented in the MD or CD. Vacuum molding with a vacuum box such as box 75 (FIG. 26) included testing with a narrow 6.35 mm (1/4") and wider 3.81 cm (1.5") slot up to about 63.5 cm (25") Hg vacuum.

[0151] Concerning the units in the tables, the following conversion factors apply:

1 mil = 0.0254 mm,

1 lbs/3000 ft^2 = 0.4563 kg/278.7 m^2,

1 g/3 inch = 0.131 g/cm.

[0152] The term 'cc' stands for 'cm^3'.

Table 4 -

Example	Description	Caliper 1 Sheet mils/ 1 sht	Void Volume Dry Wt g	Void Volume Wet Wt g	Void Volume Wt Inc. %	Void Volume Ratio	Void Volume grams/gram	Basis Weight lbs/3000 ft2
G	TAD @ 0	18.8	0.0152	0.1481	873.970	4.600	8.74	14.5
H	TAD@10% Pullout	18.5	0.0146	0.1455	900.005	4.737	9.00	13.8
I	TAD@15%	17.0	0.0138	0.1379	902.631	4.751	9.03	13.1
J	TAD@20%	16.2	0.0134	0.1346	904.478	4.760	9.04	12.8
K	CWP @ 0	52	0.0156	0.0855	449.628	2.366	4.50	14.8
L	CWP@ 10% Pullout	5.1	0.0145	0.0866	497.013	2.616	4.97	13.8
M	CWP @ 15%	5.0	0.0141	0.0830	488.119	2.569	4.88	13.4
	CWP @ 20%	4.6	0.0139	0.0793	472.606	2.487	4.73	13.2

Table 5 - Representative Examples 9-34

Description	Recovered Stretch (%)	Caliper After Recovery 1 Sheet (mils/1 sht)	Initial Caliper 1 Sheet (mils/1 sht)	Void Vol. Dry Wt (g)	Void Vol. WetWt (g)	Void Vol. Wt Inc. (%)	Void Volume Ratio	Basis Weight	Void Volume	Original Caliper	Void Volume Change
	0	16.5	16.5	0.0274	0.228	732	3.8516	26.0247	7.3180	1.0000	
Yankee-Dried	0	16.3	163	0.0269	0.221	722	3.7988	25.5489	7.2178	1.0000	
	15	15.3	16.4	0.0264	0.217	7.25	3.8162	25.0731	7.2508	0.9329	-0.0023
	15	15.4	16.4	0.0264	0.218	726	3.8220	25.1207	7.2619	0.9390	-0.0008
	25	13.7	16.5	0.0237	0.200	747	3.9333	22.5040	7.4732	0.8303	0.0283
	25	13.6	16.3	0.0240	0.198	725	3.8150	22.7894	7.2485	0.8344	-0.0027
	30	12.9	16.6	0.0227	0.191	742	3.9049	21.5524	7.4193	0.7771	0.0208
	30	13.0	16.6	0.0227	0.188	732	3.8515	21.5524	7.3178	0.7831	0.0069
	35	12.4	16.4	0.0221	0.190	760	3.9987	21.0291	7.5975	0.7561	0.0454
	35	12.4	16.4	0.0224	0.189	742	3.9065	21.3145	7.4224	0.7561	0.0213
	40	11.6	16.4	0.0213	0.187	782	4.1164	20.2203	7.8212	0.7073	0.0761
	40	11.8	16.4	0.0213	0.190	793	4.1760	20.2203	7.9344	0.7195	0.0917
	0	12.4	12.4	0.0226	0.132	482	2.5395	21.5048	4.8250	1.0000	
Can-dried	0	12.4	12.4	0.0230	0.138	503	2.6478	21.8379	5.0308	1.0000	
	20	12.6	12.7	0.0202	0.135	568	2.9908	19.2211	5.6826	0.9921	0.1531
	20	11.9	12.4	0.0200	0.130	549	2.8884	19.0308	5.4880	0.9597	0.1137
	40	11.1	12.2	0.0176	0.129	635	33427	16.6996	6.3512	0.9098	0.2888
	40	11.1	12.1	0.0177	0.128	621	3.2679	16.8423	6.2091	0.9174	0.2600
	45	11.1	12.2	0.0175	0.129	635	3.3399	16.6520	6.3457	0.9098	0.2877
	45	11.0	12.1	0.0160	0.121	654	3.4406	15.2247	6.5371	0.9091	0.3265
	50	11.1	12.8	0.0168	0.124	641	3.3762	15.9383	6.4147	0.8672	0.3017
	50	10.5	12.2	0.0162	0.122	653	3.4364	15.3674	6.5291	0.8607	0.3249
	55	103	12.1	0.0166	0.125	653	3.4395	15.7480	6.5350	0.8512	0.3261
	55	10.0	12.4	0.0165	0.123	651	3.4277	15.6529	6.5126	0.8065	0.3216
	60	9.6	12.2	0.0141	0.117	731	3.8463	13.4167	7.3080	0.7869	0.4830
	60	9.6	12.5	0.0151	0.116	673	3.5404	14.3207	6.7267	0.7680	0.3650

Table 6 - Modulus Data Can-Dried Sheet

Stretch	7 Point Modulus
0.0%	
0.1%	
0.2%	
0.2%	
0.3%	
0.3%	
0.4%	
0.4%	2.901
0.5%	0.800
0.6%	6.463
0.6%	8.599
0.7%	7.007
0.7%	9.578
0.8%	10.241
0.8%	9.671
0.9%	8.230
0.9%	8.739
1.0%	11.834
1.1%	11.704
1.1%	7.344
1.2%	4.605
1.2%	5.874
1.3%	9.812
1.3%	7.364
1.4%	7.395
1.4%	3.595
1.5%	9.846
1.6%	9.273
1.6%	9.320

Stretch	7 Point Modulus
1.7%	9.044
1.7%	8.392
1.8%	6.904
1.8%	9.106
1.9%	4.188
1.9%	9.058
2.0%	5.812
2.1%	6.829
2.1%	8.861
2.2%	8.726
2.2%	7.547
2.3%	8.551
2.3%	5.323
2.4%	8.749
2.4%	8.335
2.5%	3.565
2.6%	7.184
2.6%	10.009
2.7%	6.210
2.7%	4.050
2.8%	6.196
2.8%	6.650
2.9%	3.741
2.9%	4.788
3.0%	1.204
3.1%	4.713
3.1%	6.730
3.2%	1.970
3.2%	6.071

Stretch	7 Point Modulus
3.3%	9.930
3.3%	1.369
3.4%	6.921
3.4%	4.998
3.5%	3.646
3.6%	8.263
3.6%	1.287
3.7%	2.850
3.7%	4.314
3.8%	3.653
3.8%	4.033
3.9%	3.033
3.9%	2.546
4.0%	2.951
4.1%	-1.750
4.1%	3.651
4.2%	3.476
4.2%	1.422
4.3%	2.573
4.3%	2.629
4.4%	0.131
4.4%	7.777
4.5%	2.504
4.6%	0.845
4.6%	4.639
4.7%	2.827
4.7%	1.037
4.8%	4.396
4.8%	-0.680

Stretch	7 Point Modulus
4.9%	3.015
4.9%	4.976
5.0%	2.223
5.1%	2.288
5.1%	1.501
5.2%	-0.534
5.2%	3.253
5.3%	1.184
5.3%	0.749
5.4%	-0.231
5.4%	0.069
5.5%	2.161
5.6%	6.864
5.6%	1.515
5.7%	-0.281
5.7%	-2.001
5.8%	2.136
5.8%	4.216
5.9%	-0.066
5.9%	-0.596
6.0%	-0.031
6.1%	1.187
6.1%	1.689
6.2%	1.424
6.2%	1.363
6.3%	3.877
6.3%	0.712
6.4%	1.810

Table 6 - Modulus Data Can-Dried Sheet

Stretch	7 Point Modulus	Stretch	7 Point Modulus	Stretch	7 Point Modulus	Stretch	7 Point Modulus
6.4%	2.368	7.8%	1.187	9.2%	-2.670	10.6%	0.553
6.5%	1.531	7.9%	-0.059	9.3%	-0.091	10.7%	-0.931
6.6%	1.984	7.9%	-2.503	9.3%	-1.808	10.7%	-0.635
6.6%	0.014	8.0%	0.420	9.4%	1.817	10.8%	0.713
6.7%	-4.405	8.1%	-0.130	9.4%	-1.529	10.8%	0.040
6.7%	1.606	8.1%	-1.059	9.5%	-1.259	10.9%	0.645
6.8%	2.634	8.2%	4.016	9.6%	4.814	10.9%	0.111
6.8%	-0.467	8.2%	-0.561	9.6%	3.044	11.0%	1.532
6.9%	1.865	8.3%	0.784	9.7%	2.383	11.1%	2.753
6.9%	-3.493	8.3%	4.101	9.7%	0.411	11.1%	3.364
7.0%	1.088	8.4%	3.313	9.8%	-1.111	11.2%	-0.970
7.1%	7.333	8.4%	1.557	9.8%	1.785	11.2%	-0.717
7.1%	-0.900	8.5%	1.425	9.9%	2.055	11.3%	3.049
7.2%	-2.607	8.6%	-1.135	9.9%	-0.801	11.3%	-1.919
7.2%	3.199	8.6%	3.694	10.0%	0.466	11.4%	0.342
7.3%	1.892	8.7%	0.668	10.1%	-0.899	11.4%	0.354
7.3%	1.306	8.7%	-1.626	10.1%	0.396	11.5%	-1.510
7.4%	1.063	8.8%	-0.210	10.2%	2.543	11.6%	2.085
7.4%	-0.836	8.8%	-0.014	10.2%	0.226	11.6%	1.217
7.5%	1.785	8.9%	2.920	10.3%	1.842	11.7%	-0.780
7.6%	4.308	8.9%	3.213	10.3%	-0.704	11.7%	4.265
7.6%	-0.647	9.0%	-0.456	10.4%	2.350	11.8%	-0.565
7.7%	2.090	9.1%	3.403	10.4%	1.707	11.8%	1.150
7.7%	2.956	9.1%	2.034	10.5%	0.120	11.9%	3.509
7.8%	-0.666	9.2%	-1.436	10.6%	1.741	11.9%	1.145

Table 6 - Modulus Data Can-Dried Sheet

Stretch	7 Point Modulus	Stretch	7 Point Modulus	Stretch	7 Point Modulus	Stretch	7 Point Modulus
12.0%	1.268	18.3%	1.122	25.2%	0.959	32.2%	1.623
12.1%	1.923	18.6%	1.011	25.5%	0.896	32.4%	1.304
12.1%	-1.835	18.8%	0.756	25.8%	0.533	32.7%	1.434
12.2%	0.943	19.1%	0.292	26.1%	1.354	33.0%	1.265
12.4%	0.581	19.4%	0.257	26.3%	0.530	33.3%	1.649
12.7%	0.634	19.7%	1.411	26.6%	0.905	33.6%	1.194
13.0%	1.556	19.9%	1.295	26.9%	1.304	33.8%	1.354
13.3%	1.290	20.2%	0.467	27.2%	1.596	34.1%	0.968
13.6%	0.467	20.5%	0.858	27.4%	1.333	34.4%	0.932
13.8%	1.042	20.8%	-0.177	27.7%	1.307	34.7%	1.107
14.1%	1.116	21.1%	1.148	28.0%	0.425	34.9%	1.554
14.4%	0.339	21.3%	1.047	28.3%	1.695	35.2%	0.880
14.7%	0.869	21.6%	0.758	28.6%	0.966	35.5%	1.389
14.9%	-0.213	21.9%	0.056	28.8%	0.425	35.8%	1.876
15.2%	0.192	22.2%	1.050	29.1%	0.100	36.1%	1.733
15.5%	0.757	22.4%	0.450	29.4%	0.774	36.3%	2.109
15.8%	0.652	22.7%	1.128	29.7%	1.388	36.6%	1.920
16.1%	0.648	23.0%	0.589	29.9%	1.413	36.9%	1.854
16.3%	0.461	23.3%	0.679	30.2%	0.636	37.2%	1.480
16.6%	0.142	23.6%	0.618	30.5%	1.316	37.4%	1.780
16.9%	0.976	23.8%	1.539	30.8%	1.738	37.7%	1.441
17.2%	0.958	24.1%	0.867	31.1%	1.870	38.0%	2.547
17.4%	0.816	24.4%	1.251	31.3%	1.460	38.3%	1.780
17.7%	0.180	24.7%	1.613	31.6%	1.317	38.6%	1.762
18.0%	0.318	24.9%	0.798	31.9%	1.209	38.8%	2.129

Table 6 - Modulus Data Can-Dried Sheet

Stretch	7 Point Modulus
39.1%	2.132
39.4%	1.968
39.7%	2.307
39.9%	1.983
40.2%	1.929
40.5%	2.692
40.8%	2.018
41.1%	3.112
41.3%	2.261
41.6%	3.022
41.9%	1.739
42.2%	3.274
42.4%	2.516
42.7%	2.436
43.0%	1.949
43.3%	3.357
43.6%	1.880
43.8%	3.140
44.1%	2.899
44.4%	2.993
44.7%	3.665
44.9%	3.671
45.2%	2.694
45.5%	4.047
45.8%	3.875

Stretch	7 Point Modulus
46.1%	2.465
46.3%	3.712
46.6%	3.560
46.9%	2.967
47.2%	3.945
47.4%	3.337
47.7%	4.052
48.0%	5.070
48.3%	4.113
48.6%	4.044
48.8%	4.366
49.1%	4.639
49.4%	5.178
49.7%	4.315
49.9%	4.674
50.2%	4.061
50.5%	4.884
50.8%	6.005
51.1%	5.250
51.3%	4.888
51.6%	4.868
51.9%	5.304
52.2%	5.920
52.4%	5.849
52.7%	4.768
53.0%	5.280

Stretch	7 Point Modulus
53.3%	5.097
53.6%	6.320
53.8%	5.780
54.1%	6.064
54.4%	5.595
54.7%	6.350
54.9%	5.647
55.2%	6.049
55.5%	5.907
55.8%	5.092
56.1%	5.315
56.3%	5.821
56.6%	5.179
56.9%	5.780
57.2%	6.432
57.4%	5.358
57.7%	5.858
57.8%	5.528
58.1%	-0.539
58.3%	-4.473
58.6%	-7.596
58.8%	-16.304
59.1%	-19.957
59.3%	-27.423
59.6%	-24.870
59.8%	-24.354
60.1%	-26.042
60.2%	-33.413

Stretch	7 Point Modulus
60.3%	-33.355
60.4%	-39.617
60.5%	-49.495
60.8%	-54.166

Table 7 - Modulus Data Yankee-Dried Sheet

Stretch (%)	7 Point Modulus	Stretch (%)	7 Point Modulus	Stretch (%)	7 Point Modulus	Stretch (%)	7 Point Modulus
0.0%		1.2%	-1.383	2.3%	1.999	3.5%	3.757
0.0%		1.2%	-1.222	2.4%	0.340	3.6%	-0.541
0.1%		1.3%	0.462	2.4%	0.744	3.6%	0.524
0.2%		1.3%	3.474	2.5%	1.202	3.7%	-0.531
0.2%		1.4%	4.228	2.6%	2.405	3.7%	-0.563
0.3%		1.4%	-1.074	2.6%	1.714	3.8%	2.439
0.3%		1.5%	0.133	2.7%	-0.616	3.8%	2.976
0.4%		1.6%	-0.563	2.7%	-0.934	3.9%	-1.508
0.4%	-1.070	1.6%	1.659	2.8%	-1.307	3.9%	0.142
0.5%	1.632	1.7%	0.430	2.8%	0.976	4.0%	2.031
0.6%	-0.636	1.7%	0.204	2.9%	1.584	4.1%	2.765
0.6%	2.379	1.8%	-2.271	2.9%	2.162	4.1%	1.384
0.7%	-0.488	1.8%	0.536	3.0%	1.594	4.2%	2.172
0.7%	-0.594	1.9%	0.850	3.1%	2.895	4.2%	-0.561
0.8%	4.041	1.9%	1.918	3.1%	1.606	4.3%	2.293
0.8%	2.522	2.0%	3.341	3.2%	4.526	4.3%	0.745
0.9%	-1.569	2.1%	3.455	3.2%	1.075	4.4%	1.172
0.9%	0.684	2.1%	1.837	3.3%	1.206	4.4%	-2.196
1.0%	-1.694	2.2%	1.079	3.3%	0.414	4.5%	0.657
1.1%	1.769	2.2%	1.027	3.4%	0.611	4.6%	-1.475
1.1%	1.536	2.3%	1.637	3.4%	-0.006	4.6%	1.805

Table 7 - Modulus Data Yankee-Dried Sheet

Stretch (%)	7 Point Modulus
4.7%	-0.679
4.7%	1.787
4.8%	3.364
4.8%	3.989
4.9%	0.673
4.9%	2.903
5.0%	-0.233
5.1%	1.353
5.1%	2.525
5.2%	-1.461
5.2%	0.923
5.3%	3.618
5.3%	1.279
5.4%	1.515
5.4%	1.022
5.5%	-1.682
5.6%	1.089
5.6%	-1.423
5.7%	-0.381
5.7%	0.464
5.8%	3.053
5.8%	1.658
5.9%	4.678
5.9%	3.621
6.0%	1.960
6.1%	1.921
6.1%	0.775
6.2%	1.072
6.2%	1.441
6.3%	-1.200
6.3%	0.089
6.4%	2.611
6.4%	2.132
6.5%	0.832
6.6%	0.665
6.6%	3.531
6.7%	2.040
6.7%	0.289
6.8%	0.654
6.8%	2.516
6.9%	2.139
6.9%	1.454
7.0%	-0.256
7.1%	2.056
7.1%	2.278
7.2%	3.943
7.2%	0.398
7.3%	2.336
7.3%	-1.757
7.4%	1.079
7.4%	0.113
7.5%	-0.534
7.6%	-2.582
7.6%	0.738
7.7%	-1.566
7.7%	4.872
7.8%	0.032
7.8%	0.591
7.9%	2.197
7.9%	3.343
8.0%	-0.128
8.1%	2.866
8.1%	1.846
8.2%	2.232
8.2%	2.015
8.3%	1.955
8.3%	1.117
8.4%	2.535
8.4%	0.939
8.5%	0.684
8.6%	1.770
8.6%	1.808
8.7%	0.904
8.7%	0.990
8.8%	1.683
8.8%	1.088
8.9%	0.840
8.9%	1.290
9.0%	1.118
9.1%	1.210
9.1%	1.270
9.2%	0.469
9.2%	0.958
9.3%	1.209

Table 7 - Modulus Data Yankee-Dried Sheet

Stretch (%)	7 Point Modulus	Stretch (%)	7 Point Modulus	Stretch (%)	7 Point Modulus	Stretch (%)	7 Point Modulus
9.3%	0.845	14.3%	1.693	20.1%	0.884	25.9%	1.078
9.4%	0.841	14.6%	0.992	20.4%	1.600	26.2%	1.772
9.4%	1.195	14.8%	1.296	20.7%	0.979	26.5%	1.464
9.5%	1.445	15.1%	1.329	20.9%	0.969	26.8%	1.177
9.6%	1.655	15.4%	1.372	21.2%	0.970	27.1%	1.125
9.8%	1.449	15.7%	1.292	21.5%	1.395	27.3%	0.929
10.1%	1.206	15.9%	1.045	21.8%	1.352	27.6%	1.538
10.4%	1.309	16.2%	0.377	22.1%	1.175	27.9%	2.302
10.7%	1.269	16.5%	1.694	22.3%	0.860	28.2%	1.871
10.9%	1.102	16.8%	0.310	22.6%	0.895	28.4%	1.425
11.2%	1.258	17.1%	0.637	22.9%	1.456	28.7%	1.751
11.5%	0.870	17.3%	0.929	23.2%	1.254	29.0%	1.368
11.8%	1.237	17.6%	1.506	23.4%	1.140	29.3%	2.044
12.1%	0.804	17.9%	1.005	23.7%	0.913	29.6%	1.522
12.3%	1.020	18.2%	1.360	24.0%	1.293	29.8%	0.797
12.6%	0.753	18.4%	0.723	24.3%	0.674	30.1%	1.208
12.9%	1.285	18.7%	1.746	24.6%	1.326	30.4%	1.567
13.2%	0.813	19.0%	1.706	24.8%	1.071	30.7%	1.396
13.4%	1.073	19.3%	1.339	25.1%	1.386	30.9%	2.030
13.7%	0.870	19.6%	0.488	25.4%	1.253	31.2%	1.196
14.0%	1.327	19.8%	1.269	25.7%	1.467	31.5%	1.311

Table 7 - Modulus Data Yankee-Dried Sheet

Stretch (%)	7 Point Modulus
31.8%	1.528
32.1%	1.803
32.3%	1.424
32.6%	1.627
32.9%	1.458
33.2%	2.377
33.4%	2.158
33.7%	1.866
34.0%	1.749
34.3%	1.924
34.6%	2.075
34.8%	2.551
35.1%	1.869
35.4%	2.248
35.7%	2.498

Stretch (%)	7 Point Modulus
35.9%	2.400
36.2%	3.339
36.5%	2.649
36.8%	2.267
37.1%	2.878
37.3%	2.005
37.6%	2.636
37.9%	2.793
38.2%	2.104
38.4%	2.511
38.7%	2.605
39.0%	2.521
39.3%	2.875
39.6%	2.766
39.8%	2.753

Stretch (%)	7 Point Modulus
40.1%	2.619
40.4%	2.698
40.7%	3.165
40.9%	3.134
41.2%	4.025
41.5%	4.118
41.8%	4.165
42.1%	3.912
42.3%	4.667
42.6%	3.692
42.9%	3.871
43.2%	3.261
43.4%	3.661
43.7%	3.470
44.0%	4.725
44.3%	3.424

Stretch (%)	7 Point Modulus
44.6%	3.444
44.8%	4.148
45.1%	5.041
45.4%	3.676
45.7%	4.125
45.9%	3.372
46.2%	3.748
46.5%	4.368
46.8%	3.565
46.8%	3.132
47.1%	2.726
47.4%	-4.019
47.4%	-10.656
47.5%	-21.712
47.6%	-45.557
47.6%	-62.257

Table 8 - Caliper Gain Comparison Representative Examples 35-56

Roll Number Count	Vac Level	Long Fabric Strands to Sheet	Molding Box Slot Width. Inches	Fabric Crepe Ratio	Caliper mils/8 sht	Basis Weight Lb/3000 ft^2	Tensile GM g/3 in.	Cal/Bwt cc/gram	Void Volume grams/gram
7306	0	MD	0.25	1.30	65.18	13.82	718	9.2	7.4
7307	10	MD	0.25	1.30	77.05	13.21	624	11.4	7.6
7308	5	MD	1.50	1.30	68.60	13.51	690	9.9	7.2
7309	10	MD	1.50	1.30	77.70	1325	575	11.4	6.7
7310	20	MD	0.25	1.30	88.75	13.19	535	13.1	
7311	20	MD	0.25	1.30	91.05	13.24	534	13.4	8.2
7312	20	MD	1.50	1.30	87.73	13.23	561	12.9	8.4
7313	0	MD	1.50	1.33	64.83	13.50	619	9.4	
7314	0	MD	1.50	1.30	64.18	13.47	611	9.3	
7315	5	MD	0.25	1.30	70.55	13.38	653	10.3	
7316	0	MD	0.25	1.15	52.58	13.23	1063	7.7	
7317	0	MD	0.25	1.15	53.05	13.12	970	7.9	6.3
7318	5	MD	0.25	1.15	57.40	13.20	1032	8.5	6.5 r
7319	10	MD	0.25	1.15	62.45	13.01	969	9.4	6.7
7320	5	MD	1.50	1.15	54.65	12.98	1018	8.2	8.0
7321	10	MD	1.50	1.15	62.43	13.02	991	9.3	9.3 82
7322	20	MD	1.50	1.15	71.40	13.08	869	10.6	7.5
7323	24	MD	0.25	1.15	77.68	13.21	797	11.5	
7324	0	MD	0.25	1.15	75.75	23.53	1518	6.3	
7325	0	MD	0.25	1.15	78.90	24.13	1488	6.4	
7326	0	MD	0.25	1.15	78.40	24.53	1412	6.2	5.8
7327	15	MD	0.25	1.15	83.93	24.09	1314	5.8	6.1

Table 8 - Caliper Gain Comparison Representative Examples 57-78

Roll Number Count	Vac Level	Long Fabric Strands to Sheet	Molding Box Slot Width. Inches	Fabric Crepe Ratio	Caliper mils/ 8 sht	Basis Weight Lb/3000 ft^2	Tensile GM g/3 in.	Cal/Bwt cc/gram	Void Volume grams/ gram
7328	10	MD	1.50	1.15	83.18	24.15	1280	6.7	6.2
7329	20	MD	0.25	1.15	88.35	24.33	1316	7.1	6.2
7330	15	MD	1.50	1.15	86.55	24.40	1364	6.9	6.3
7331	24	MD	1.50	1.15	93.03	24.43	1333	7.4	6.4
7332	24	MD	0.25	1.15	93.13	24.62	1264	7.4	6.5
7333	5	MD	0.25	1.15	79.10	24.68	1537	6.2	5.9
7334	0	MD	0.25	1.30	92.00	25.16	779	7.1	
7335	0	MD	0.25	1.30	90.98	24.89	1055	7.1	
7336	0	MD	0.25	1.30	91.45	24.15	1016	7.4	6.3
7337	5	MD	0.25	1.30	90.13	23.98	1022	7.3	6.5
7338	10	MD	0.25	1.30	94.93	23.92	980	7.7	6.6
7339	5	MD	1.50	1.30	9523	24.05	1081	7.7	6.6
7340	20	MD	0.25	1.30	103.20	23.43	961	8.6	
7341	15	MD	1.50	1.30	99.88	23.60	996	8.2	6.5
7342	20	MD	1.50	1.30	104.83	24.13	934	8.5	7.1
7343	24	MD	0.25	1.30	106.20	23.98	903	8.6	6.7
7344	24	MD	0.25	1.30	111.20	23.93	876	9.1	
7345	0	MD	0.25	1.30	92.08	24.44	967	7.3	6.7
7346	15	MD	0.25	1.30	102.90	23.89	788	8.4	7.2
7347	15	MD	0.25	1.15	91.68	24.15	1159	7.4	6.5
7348	0	MD	0.25	1.15	83.98	24.27	1343	6.7	6.5
7349	24	MD	0.25	1.15	96.43	23.91	1146	7.9	6.9

Table 8 - Caliper Gain Comparison Representative Examples 79-100

Roll Number Count	Vac Level	Long Fabric Strands to Sheet	Molding. Box Slot Width. Inches	Fabric Crepe Ratio	Caliper mils/ 8 sht	Basis Weight Lb/3000 ft^2	Tensile GM g/3 in.	Cal/Bwt cc/gram	Void Volume grams/ gram
7351	0	CD	0.25	1.15	86.65	24.33	1709	6.9	
7352	0	CD	0.25	1.15	87.60	24.62	1744	6.9	5.9
7353	5	CD	0.25	1.15	88.60	24.76	1681	7.0	5.6
7354	15	CD	0.25	1.15	100.58	24.50	1614	8.0	6.2
7355	24	CD	0.25	1.15	100.33	24.44	1638	8.0	6.3
7356	0	CD	1.50	1.15	88.40	24.18	1548	7.1	
7357	0	CD	1.50	1.15	87.05	24.12	1565	7.0	
7358	24	CD	1.50	1.15	99.30	24.17	1489	8.0	

(continued)

Roll Number Count	Vac Level	Long Fabric Strands to Sheet	Molding. Box Slot Width. Inches	Fabric Crepe Ratio	Caliper mils/ 8 sht	Basis Weight Lb/3000 ft^2	Tensile GM g/3 in.	Cal/Bwt cc/gram	Void Volume grams/ gram
7359	24	CD	0.25	1.15	104.08	24.21	1407	8.4	
7360	0	CD	0.25	1.15	91.18	24.13	1415	7.4	6.3
7361	5	CD	025	1.15	92.43	24.18	1509	7.4	6.3
7362	15	CD	0.25	1.15	102.15	24.21	1506	8.2	6.7
7363	24	CD	0.25	1.15	104.50	24.58	1476	8.3	6.7
7364	24	CD	0.25	1.30	119.45	24.72	1056	9.4	
7365	24	CD	0.25	1.30	123.25	24.46	352	9.8	
7366	24	CD	0.25	1.30	124.30	24.62	1041	9.8	7.0
7367	0	CD	0.25	1.30	100.18	24.52	1019	8.0	6.6
7368	15	CD	0.25	1.30	113.95	24.29	1023	9.1	6.8
7369	5	CD	0.25	1.30	106.55	24.56	1106	8.5	6.6
7370	0	CD	0.25	1.30	96.28	24.68	1238	7.6	6.1
7371	5	CD	0.25	1.30	98.80	24.65	1239	7.8	6.1
7372	15	CD	0.25	1.30	109.80	24.64	1110	8.7	6.4

Table 8 - Caliper Gain Comparison Representative Examples 101-122

Roll Number Count	Vac Level	Long Fabric Strands to Sheet	Molding Box Slot Width. Inches	Fabric Crepe Ratio	Caliper mils/ 8 sht	Basis Weight Lb/3000 ft^2	Tensile GM g/3 in.	Cal/Bwt cc/gram	Void Volume grams/ gram
7373	24	CD	0.25	1.30	114.65	24.75	1182	9.0	6.6
7376	0	CD	0.25	1.30	70.88	13.32	723	10.4	6.5
7377	5	CD	0.25	1.30	80.48	13.38	629	11.7	7.5
7378	15	CD	0.25	1.30	100.90	13.71	503	14.3	8.8
7379	20	CD	0.25	1.30	112.55	13.87	468	15.8	9.2
7380	20	CD	0.25	1.30	112.60	12.80	345	17.1	9.8
7381	15	CD	0.25	1.30	103.93	12.96	488	15.6	9.1
7382	5	CD	0.25	1.30	91.35	13.06	499	13.6	7.8
7383	0	CD	0.25	1.30	73.03	13.17	613	10.8	8.4
7386	0	CD	0.25	1.15	59.35	13.21	1138	8.8	5.9
7387	5	CD	0.25	1.15	64.35	13.20	1153	9.5	6.1
7388	15	CD	0.25	1.15	77.43	13.22	1109	11.4	6.7
7389	24	CD	0.25	1.15	83.38	13.31	971	12.2	7.4
1390	24	CD	0.25	1.15	87.28	13.20	895	12.9	7.6
7391	15	CD	0.25	1.15	82.58	13.02	935	12.4	7.2
7392	5	CD	0.25	1.15	68.58	12.97	1000	10.3	6.2

(continued)

Roll Number Count	Vac Level	Long Fabric Strands to Sheet	Molding Box Slot Width. Inches	Fabric Crepe Ratio	Caliper mils/ 8 sht	Basis Weight Lb/3000 ft^2	Tensile GM g/3 in.	Cal/Bwt cc/gram	Void Volume grams/ gram
7393	0	CD	0.25	1.15	61.40	12.92	952	9.3	6.3
7394	0	CD	0.25	1.15	57.35	12.67	878	8.8	
7395	0	CD	0.25	1.15	57.45	12.83	924	8.7	
7396	0	CD	0.25	1.15	58.50	13.50	1053	8.4	6.2
7397	5	CD	0.25	1.15	63.75	13.20	1094	9.4	6.5
7398	15	CD	0.25	1.15	79.08	13.95	878	11.0	6.9

Table 8 - Caliper Gain Comparison Representative Examples 123-144

Roll Number Count	Vac Level	Long Fabrics Strands to Sheet	Molding Box Slot Width. Inches	Fabric Crepe Ratio	Caliper mils/ 8 sht	Basis Weight Lb/3000 ft^2	Tensile GM g/3 in.	Cal/Bwt cc/gram	Void Volume grams/ gram
7399	24	CD	0.25	1.15	82.50	13.44	811	12.0	6.7
7400	24	CD	0.25	1.30	96.88	13.68	566	13.8	
7401	24	CD	0.25	1.30	96.78	13.70	556	13.8	7.9
7402	15	CD	0.25	1,30	91.00	13.75	585	12.9	8.1
7403	5	CD	0.25	1.30	76.03	13.50	633	11.0	6.9
7404	0	CD	0.25	1.30	69.98	13.19	605	10.3	7.2
7405	0	CD	0.25	1.30	96.58	24.55	1091	7.7	
7406	0	CD	0.25	1.30	94.05	24.17	1023	7.6	6.4
7407	5	CD	0.25	1.30	93.65	24.41	888	7.5	6.5
7408	15	CD	0.25	1.30	99.13	24.31	1051	7.9	7.0
7409	24	CD	0.25	1.30	104.48	24.47	988	8.3	7.0
7410	24	CD	0.25	1.15	100.38	24.40	1278	8.0	
7411	24	CD	0.25	1.15	97.33	24.33	1302	7.8	
7412	24	CD	0.25	1.15	96.83	24.73	1311	7.6	
7413	24	CD	0.25	1.15	96.00	24.58	1291	7.6	5.9
7414	15	CD	0.25	1.15	91.88	24.41	1477	7.3	6.2
7415	5	CD	0.25	1.15	84.88	24.37	1521	6.8	6.0
7416	0	CD	0.25	1.15	83.60	23.89	1531	6.8	6.1
7417	0	CD	0.25	1.15	85.33	23.72	1310	7.0	6.2
7418	24	CD	0.25	1.15	103.48	24.05	1252	8.4	6.1
7419	24	CD	0.25	1.30	108.75	24.37	979	8.7	
7420	24	CD	0.25	1.30	113.00	24.23	967	9.1	7.4

Table 8 - Caliper Gain Comparison Representative Examples 145-166

Roll Number Count	Vac Level	Long Fabric Strands to Sheet	Molding Box Slot Width. Inches	Fabric Crepe Ratio	Caliper mils/ 8 sht	Basis Weight Lb/3000 ft^2	Tensile GM g/3 in.	Cal/Bwt cc/gram	Void Volume grams/ gram
7421	0	CD	0.25	1.30	94.43	24.27	954	7.6	6.6
7423	0	MD	0.25	1.30	94.00	24.75	1164	7.4	
7424	0	MD	0.25	1.30	93.83	24.41	969	7.5	8.5
7425	5	MD	0.25	1.30	94.55	23.96	1018	7.7	6.8
7426	15	MD	0.25	1.30	110.53	24.17	1018	8.9	6.7
7427	24	MD	0.25	1.30	115.93	24.39	997	9.3	6.9
7428	24	MD	0.25	1.30	122.83	23.86	834	10.0	
7429	0	MD	0.25	1.30	95.40	23.88	915	7.8	
7430	0	MD	0.25	1.15	78.25	24.15	1424	6.3	
7431	0	MD	0.25	1.15	80.30	23.60	1365	6.6	
7432	0	MD	0.25	1.15	80.53	23.91	1418	6.6	6.0
7433	5	MD	0.25	1.15	81.50	24.37	1432	6.5	5.9
7434	15	MD	0.25	1.15	94.43	23.84	1349	7.7	6.2
7435	24	MD	0.25	1.15	101.90	24.22	1273	8.2	6.6
7438	0	MD	0.25	1.30	72.53	13.82	475	10.2	
7439	0	MD	0.25	1.30	71.63	13.47	478	10.4	7.9
7440	5	MD	0.25	1.30	82.75	13.70	541	11.8	7.7
7441	15	MD	0.25	1.30	102.48	13.77	529	14.5	7.8
7442	24	MD	0.25	1.30	104.23	13.80	802	14.7	8.3
7446	0	MD	0.25	1.30	87.08	24.39	1155	7.0	
7447	0	MD	0.25	1.30	88.53	24.41	1111	7.1	
7448	5	MD	0.25	1.30	90.60	24.50	1105	7.2	6.5

Table 8 - Caliper Gain Comparison Representative Examples 167-187

Roll Number Count	Vac Level	Long Fabric Strands to Sheet	Molding Box Slot Width. Inches	Fabric Crepe Ratio	Caliper mils/ 8 sht	Basis Weight Lb/3000 ft^2	Tensile GM g/3 in.	Cal/Bwt cc/gram	Void Volume grams/ gram
7449	5	MD	0.25	1.30	89.15	24.59	1085	7.1	6.3
7450	15	MD	0.25	1.30	99.03	24.26	1014	8.0	6.8
7451	24	MD	0.25	1.30	106.90	24.54	960	8.5	7.4
7452	24	MD	0.26	1.15	87.23	23.90	1346	7.1	
7453	24	MD	0.25	1.15	94.05	23.54	1207	7.8	7.2
7454	15	MD	0.25	1.15	87.38	24.15	1363	7.1	6.2
7455	5	MD	0.25	1.15	79.40	24.27	1476	6.4	5.9
7456	0	MD	0.25	1.15	79.45	23.89	1464	6.5	6.1

(continued)

Roll Number Count	Vac Level	Long Fabric Strands to Sheet	Molding Box Slot Width. Inches	Fabric Crepe Ratio	Caliper mils/ 8 sht	Basis Weight Lb/3000 ft^2	Tensile GM g/3 in.	Cal/Bwt cc/gram	Void Volume grams/ gram
7457	0	CD	0.25	1.15	88.00	24.48	1667	7.0	
7458	0	CD	0.25	1.15	88.43	24.15	1705	7.1	
7459	0	CD	0.25	1.15	87.88	24.32	1663	7.0	6.0
7460	5	CD	0.25	1.15	87.13	24.01	1639	7.1	6.2
7461	15	CD	0.25	1.15	99.50	24.18	1580	8.0	6.7
7462	24	CD	0.25	1.15	107.68	24.68	1422	8.5	7.3
7463	24	CD	0.25	1.30	118.33	25.38	1008	9.1	
7464	24	CD	0.25	1.30	123.75	24.57	1056	9.8	
7465	24	CD	0.25	1.30	120.00	24.86	1035	9.4	
7466	15	CD	0.25	1.30	113.10	24.28	1072	9.1	6.4
7467	15	CD	025	1.30	110.25	24.49	1092	8.8	72
7468	0	CD	0.25	1.30	97.70	24.38	1095	7.8	6.5
7469	0	CD	0.25	1.30	96.83	23.09	1042	8.2	5.6

Table 9 - Caliper Change With Vacuum

Fabric Ct	Fabric Type	Fabric Orientation	Basis Weight	Fabric Crepe Ratio	Slope	Intercept	Caliper @ 25 in Hg
44	M	MD	13	1.15	1.0369	51.7	77.6
44	G	CD	13	1.15	1.1449	57.9	86.6
44	M	CD	13	1.15	1.1464	59.8	88.4
44	M	MD	13	1.30	1.3260	64.0	97.1
44	G	CD	13	1.30	1.1682	70.5	99.7
44	G	MD	13	1.30	1.5370	73.2	111.6
44	M	CD	13	1.30	1.9913	72.6	122.4
36	M	MD	24	1.15	0.5189	78.4	91.4
44	M	MD	24	1.15	0.6246	78.2	93.8
44	G	CD	24	1.15	0.6324	83.3	99.2
44	G	MD	24	1.15	0.9689	78.9	103.1
44	M	CD	24	1.15	0.6295	88.1	103.8
36	M	CD	24	1.15	0.8385	86.7	107.7
44	M	MD	24	1.30	0.6771	90.2	107.1
36	M	MD	24	1.30	0.8260	86.6	107.2
44	G	CD	24	1.30	0.5974	93.5	108.4
44	G	MD	24	1.30	1.1069	92.7	120.4
44	M	CD	24	1.30	0.9261	97.6	120.7
36	M	CD	24	1.30	0.9942	96.7	121.6

Table 10 - Void Volume Change With Vacuum

Fabric Ct	Fabric Type	Fabric Orientation	Basis Weight	Fabric Crepe Ratio	Slope	Intercept	VV@ 25 in Hg
44	G	CD	13	1.15	0.0237	6.3	6.9
44	M	CD	13	1.15	0.0617	6.0	7.6
44	M	MD	13	1.15	0.0653	6.0	7.6
44	G	MD	13	1.30	0,0431	7.0	8.1
44	G	CD	13	1.30	0.0194	7.7	8.2
44	M	MD	13	1.30	0.0589	7.0	8.4
44	M	CD	13	1.30	0.1191	7.1	10.1
44	G	CD	24	1.15	-0.0040	6.1	6.0
44	M	MD	24	1.15	0.0204	6.0	6.5
44	G	MD	24	1.15	0.0212	6.0	6.5
44	G	CD	24	1.15	0.0269	5.9	6.6
36	M	MD	24	1.15	0.0456	5.8	7.0
36	M	CD	24	1.15	0.0539	5.9	7.3
44	M	CD	24	1.30	0.0187	6.3	6.8
44	G	MD	24	1.30	0.0140	6.6	6.9
44	M	MD	24	1.30	0.0177	6.5	6.9
36	M	CD	24	1.30	0.0465	6.1	7.2
44	G	CD	24	1.30	0.0309	6.5	7.3
36	M	MD	24	1.30	0.0516	6.1	7.4

Table 11 - CD Stretch Change With Vacuum

Fabric Ct	Fabric Type	Fabrics Orientation	Basis Weight	Fabric Crepe Ratio	Slope	Intercept	Stretch @25 in Hg
44	M	MD	13	1.15	0.0582	4.147	5.6
44	G	CD	13	1.15	0.0836	4.278	6.4
44	G	CD	13	1.30	0.0689	6.747	8.5
44	M	MD	13	1.30	0.1289	6.729	10.0
44	G	MD	13	1.30	0.0769	8.583	10.5
36	M	MD	24	1.15	0.0279	4.179	4.9
44	M	MD	24	1.15	0.0387	4.526	5.5
44	G	MD	24	1.15	0.0534	4.265	5.6
36	M	MD	24	1.30	0.0634	5.589	7.2
44	G	MD	24	1.30	0.0498	6.602	7.8
44	M	MD	24	1.30	0.0596	6.893	8.4

Table 12 TMI Friction Data

Fabric	Stretch (%)	TMI Friction Top (Unitless)	TMI Friction Bottom (Unitless)
Yankee-Dried	0	0.885	1.715
	0	1.022	1.261
	15	0.879	1.444
	15	0.840	1.235
	25	1.237	1.358
	25	0.845	1.063
	30	1.216	1.306
	30	0.800	0.844
	35	1.221	1.444
	35	0.871	1.107
	40	0.811	0.937
	40	1.086	1.100
Can-Dried	0	0.615	3.651
	0	0.689	1.774
	20	0.859	2.100
	20	0.715	2.144
	40	0.607	2.587
	40	0.748	2.439
	45	0.757	3.566
	45	0.887	2.490
	50	0.724	2.034
	50	0.929	2.188
	55	0.947	1.961
	55	1.213	1.631
	60	0.514	2.685
	60	0.655	2.102

[0153] It is seen in FIG. 31 that the can-dried materials exhibit more void volume gain as the basis weight is reduced when the sheet as drawn. Moreover, the Yankee-dried and blade-creped material did not exhibit any significant void volume gain until relatively large elongation.

[0154] In Table 6 and Table 7 as well as FIGS. 32 and 33, it is seen that can-dried material and Yankee-dried material exhibit similar stress/strain behavior; however, the can-dried material has a higher initial modulus which may be beneficial to runnability. Modulus is calculated by dividing the incremental stress (per inch of sample width) in lbs by the additional elongation observed. Nominally, the quantity has units lbs/in^2.

[0155] FIG. 34 is a plot of caliper versus basis weight as the product is drawn. The Yankee-dried, aggressively creped web exhibited approximately 1:1 loss of caliper with basis weight (i.e., approximately constant bulk) whereas the can-dried web lost much more basis weight than caliper. This result is consistent with the data set of Examples 1-8 and with the void volume data. The ratio of percent decrease in basis weight may be calculated and compared for the different processes. The Yankee-dried material has an undrawn basis weight of about 11.8 kg (26 lbs) and a caliper loss of about 28% when drawn to a basis weight of about 9.3 kg (20.5 lbs); that is, the material has only about 72% of its original caliper. The basis weight loss is about 5.5/26 or 21 %; thus, the ratio of percent decrease in caliper/percent decrease in basis weight is approximately 28/21 or 1.3. It is seen in FIG. 34 that the can-dried material loses caliper much more slowly with basis weight reduction as the material is drawn. As the can-dried sheet is drawn from a basis weight of about 10 kg (22 lbs) to about 6.4 kg (14 lbs), only about 20% of the caliper is lost; and the ratio of % decrease in caliper/percent decrease in basis weight is about 20/36 or 0.55.

[0156] Results for Yankee-dried and can-dried material upon drawing is summarized graphically in FIG. 35. It is again seen here that the caliper of the can-dried material changes less than that of the Yankee-dried material as the basis weight is reduced. Moreover, large changes in void volume are observed when the can-dried material is drawn.

[0157] In FIG. 36 it is seen that caliper is influenced by selection of vacuum and creping fabric; while Table 12 and FIG. 37 show that the in-fabric can-dried material exhibited much higher TMI Friction values. In general, friction values decrease as the material is drawn. It will be appreciated from the data in Table 12 and FIG. 37 that even though samples were run only in the MD, that as the samples were drawn the friction values on either side of the sheet converge; for example the can-dried samples had average values of 2.7/0.65 fabric side/can side prior to drawing and average values of 1.8/1.1 at 55% draw.

[0158] Differences between products of the invention and conventional products are particularly appreciated by reference to Table 4 and FIG. 38. It is seen that conventional through dried (TAD) products do not exhibit substantial increases in void volume (<5%) upon drawing and that the increase in void volume is not progressive beyond 7% draw; that is, the void volume does not increase significantly (less than 1%) as the web is drawn beyond 10%. The conventional wet press (CWP) towel tested exhibited a modest increase in void volume when drawn to 10% elongation; however the void volume decreased at more elongation, again not progressively increasing. The products of the present invention exhibited large, progressive increases in void volume as they are drawn. Void volume increases of 20%, 30%, 40% and more are readily achieved.

[0159] Further differences between the inventive process and product and conventional products and processes are seen in FIG. 39. FIG. 39 is a plot of MD/CD tensile ratio (strength at break) versus the difference between headbox jet velocity and forming wire speed (fpm). The upper U-shaped curve is typical of conventional wet-press absorbent sheet. The lower, broader, curve is typical of fabric-creped product of the invention. It is readily appreciated from FIG. 39 that MD/CD tensile ratios of below 1.5 or so are achieved in accordance with the invention over a wide range of jet to wire velocity deltas, a range which is more than twice that of the CWP curve shown. Thus control of the headbox jet/forming wire velocity delta may be used to achieve desired sheet properties.

[0160] It is also seen from FIG. 39 that MD/CD ratios below square (i.e. below 1) are difficult; if not impossible to obtain with conventional processing. Furthermore, square or below sheets are formed by way of the invention without excessive fiber aggregates or "flocs" which is not the case with the CWP products having low MD/CD tensile ratios. This difference is due, in part, to the relatively low velocity deltas required to achieve low tensile ratios in CWP products and may be due in part to the fact that fiber is redistributed on the creping fabric when the web is creped from the transfer surface in accordance with the invention. Surprisingly, square products of the invention resist propagation of tears in the CD and exhibit a tendency to self-healing. This is a major processing advantage since the web, even though square, exhibits reduced tendency to break easily when being wound.

[0161] In many products, the cross machine properties are more important than the MD properties, particularly in commercial toweling where CD wet strength is critical. A major source of product failure is "tabbing" or tearing off only a piece of towel rather than the entirety of the intended sheet. In accordance with the invention, CD tensiles may be selectively elevated by control of the headbox to forming wire velocity delta and fabric creping.

[0162] In view of the foregoing discussion, relevant knowledge in the art and references including co-pending applications discussed above in connection with the Background and Detailed Description, further description is deemed unnecessary.

Claims

1. A method of making a fabric-creped absorbent cellulosic sheet (74), the method comprising:

(a) applying a jet of papermaking furnish to a forming wire (52), the jet having a jet velocity and the forming wire (52) moving at a forming wire velocity, the calculated value of the jet velocity minus the forming wire velocity being referred to as the jet/wire velocity delta;
(b) compactively dewatering the papermaking furnish to form a nascent web (74);
(c) applying the nascent web (74) to a transfer surface (94) that is moving at a transfer surface speed;
(d) fabric-creping the nascent web (74) from the transfer surface (94) at a consistency of from about 30 to about 60 percent utilizing a creping fabric (48) that is traveling at a fabric-creping speed, the fabric-creping speed being lower than the transfer surface speed, the fabric-creping step occurring under pressure in a fabric creping nip (106) defined between the transfer surface (94) and the creping fabric (48), wherein the fabric pattern, the nip parameters, the velocity delta, and the web consistency are selected such that the nascent web (74) is creped from the transfer surface (94) and redistributed on the creping fabric (48) to form a creped web (74) with a reticulum having a plurality of interconnected regions of different local basis weights, including at least (i) a plurality of fiber enriched regions (12) having a high local basis weight, interconnected by way of (ii) a plurality of lower local basis weight linking regions (14);
(e) drying the creped web (74);
characterized in that the method further comprises:
(f) controlling the jet/wire velocity delta and the fabric-creping step, including selection of the fabric, such that the plurality of fiber-enriched regions (12) have an orientation bias in the cross-machine direction (CD), and the dry machine direction to cross-machine direction (MD/CD) tensile ratio of the dried web (74) is about at most

1.5, with the proviso that the jet/wire velocity delta is greater than about 1.78 m/s (350 fpm).

2. The method according to claim 1, further including controlling the jet/wire velocity delta and the fabric-creping step such that the dry MD/CD tensile ratio of the dried web is about at most 1.

3. The method according to claim 1, further including controlling the jet/wire velocity delta and the fabric-creping step such that the dry MD/CD tensile ratio of the dried web is about at most 0.75.

4. The method according to claim 1, further including controlling the jet/wire velocity delta and the fabric-creping step such that the dry MD/CD tensile ratio of the dried web is about at most 0.5.

5. The method according to claim 1, wherein the jet/wire velocity delta is greater than about 2.03 m/s (400 fpm).

6. The method according to claim 1, wherein the jet/wire velocity delta is greater than about 2.23 m/s (450 fpm).

Patentansprüche

1. Verfahren zum Herstellen einer gewebegekreppten absorbierenden Zellulosebahn (74), wobei das Verfahren Folgendes umfasst:

(a) das Aufbringen eines Strahl von einer Papiermasse auf einen Formdraht (52), wobei der Strahl eine Strahlgeschwindigkeit aufweist und der Formdraht (52) sich mit einer Formdrahtgeschwindigkeit bewegt, wobei der berechnete Wert der Strahlgeschwindigkeit minus der Formdrahtgeschwindigkeit als die Strahl / Drahtgeschwindigkeitsdifferenz bezeichnet wird;
(b) das verdichtende Entwässern der Papiermasse, um eine entstehende Bahn (74) zu formen,
(c) das Aufbringen der entstehenden Bahn (74) auf eine Übertragungsfläche (94), die sich mit einer Übertragungsflächengeschwindigkeit bewegt,
(d) das Gewebekreppen der entstehenden Bahn (74) von der Übertragungsfläche (94) bei einer Konsistenz von etwa 30 bis etwa 60 Prozent unter Benutzung eines Kreppgewebes (48), das sich mit einer Gewebekreppgeschwindigkeit bewegt, wobei die Gewebekreppgeschwindigkeit langsamer ist als die Übertragungsflächengeschwindigkeit, wobei der Gewebekreppschritt unter Druck in einem Gewebekrepp-Walzenspalt (106) stattfindet, der zwischen der Übertragungsfläche (94) und dem Kreppgewebe (48) definiert wird, wobei das Gewebemuster, die Walzenspaltparameter, die Geschwindigkeitsdifferenz und die Bahnkonsistenz derart gewählt werden, dass die entstehende Bahn (74) von der Übertragungsfläche (94) gekreppt und auf dem Kreppgewebe (48) neu verteilt wird, um eine gekreppte Bahn (74) mit einem Netz zu bilden, das mehrere miteinander verbundene Bereiche mit unterschiedlichen örtlichen Flächengewichten aufweist, und wenigstens Folgendes umfasst:

(i) mehrere faserangereicherte Bereiche (12) mit einem hohen örtlichen Flächengewicht, miteinander verbunden mit Hilfe von
(ii) mehreren Verbindungsbereichen (14) mit einem niedrigeren örtlichen Flächengewicht,

(e) das Trocknen der gekreppten Bahn (74);
dadurch gekennzeichnet, dass das Verfahren weiterhin umfasst:
(f) das Kontrollieren der Strahl / Drahtgeschwindigkeitsdifferenz und des Gewebekreppschritts, umfassend die Auswahl des Gewebes, so dass die mehreren faserangereicherte Bereiche (12) eine Ausrichtungstendenz quer zur Maschinenrichtung (CD) aufweisen, und das trockene Maschinenrichtung zu Quermaschinenrichtung (MD/CD) Zug-Verhältnis der getrockneten Bahn (74) etwa höchstens 1,5 beträgt, mit dem Vorbehalt, dass die Strahl / Drahtgeschwindigkeitsdifferenz grösser ist als ungefähr 1.78 m/s (350 fpm).

2. Verfahren nach Anspruch 1, weiterhin umfassend das Kontrollieren der Strahl / Drahtgeschwindigkeitsdifferenz und des Gewebekreppschritts, so dass das trockene MD/CD Zug-Verhältnis der getrockneten Bahn etwa höchstens 1 beträgt.

3. Verfahren nach Anspruch 1, weiterhin umfassend das Kontrollieren der Strahl / Drahtgeschwindigkeitsdifferenz und des Gewebekreppschritts, so dass das trockene MD/CD Zug-Verhältnis der getrockneten Bahn etwa höchstens 0,75 beträgt.

4. Verfahren nach Anspruch 1, weiterhin umfassend das Kontrollieren der Strahl / Drahtgeschwindigkeitsdifferenz und des Gewebekreppschritts, so dass das trockene MD/CD Zug-Verhältnis der getrockneten Bahn etwa höchstens 0,5 beträgt.

5. Verfahren nach Anspruch 1, wobei die Strahl / Drahtgeschwindigkeitsdifferenz grösser ist als ungefähr 2,03 m/s (400 fpm).

6. Verfahren nach Anspruch 1, wobei die Strahl / Drahtgeschwindigkeitsdifferenz grösser ist als ungefähr 2,23 m/s (450 fpm).

Revendications

1. Procédé de fabrication d'une feuille cellulosique absorbante (74) crêpée à la toile, le procédé comprenant :

(a) l'application d'un jet de composition papetière à une toile formatrice (52), le jet ayant une certaine vitesse et la toile formatrice (52) se déplaçant à la vitesse de la toile formatrice, la valeur calculée de la vitesse du jet moins la vitesse de la toile formatrice étant dénommée différence (delta) de vitesses jet/toile ;
(b) l'essorage compact de la composition papetière pour former une bande naissante (74) ;
(c) l'application de la bande naissante (74) à une surface de transfert (94) qui se déplace à une vitesse de surface de transfert ;
(d) le crêpage à la toile de la bande naissante (74) à partir de la surface de transfert (94) à une concentration d'environ 30 à environ 60 pour cent en utilisant une toile de crêpage (48) qui progresse à une vitesse de crêpage à la toile, la vitesse de crêpage à la toile étant plus lente que la vitesse de la surface de transfert, l'étape de crêpage à la toile ayant lieu sous une pression dans un espacement de crêpage à la toile (106) défini entre la surface de transfert (94) et la toile de crêpage (48), dans lequel le motif de la toile, les paramètres d'espacement, la différence de vitesses et la concentration de bande sont choisis de sorte que la bande naissante (74) soit crêpée à partir de la surface de transfert (94) et redistribuée sur la toile de crêpage (48) afin de former une bande crêpée (74) dotée d'un réticulum comprenant une pluralité de régions interconnectées de différents poids de base locaux, comprenant au moins (i) une pluralité de régions enrichies en fibres (12) ayant un poids de base local élevé, interconnectées au moyen de (ii) une pluralité de régions de liaison de poids de base local inférieur (14) ;
(e) le séchage de la bande crêpée (74) ;
caractérisé en ce que le procédé comprend en outre :
(f) la régulation de la différence de vitesses jet/toile et de l'étape de crêpage à la toile, notamment la sélection de la toile de sorte que la pluralité de régions enrichies en fibres (12) aient un écart d'orientation dans le sens travers (ST) et que le rapport de traction à sec du sens machine au sens travers (SM/ST) de la bande séchée (74) soit au maximum d'environ 1,5, à condition que la différence de vitesses jet/toile soit supérieure à environ 1,78 m/s (350 fpm).

2. Procédé selon la revendication 1, comprenant en outre la régulation de la différence de vitesses jet/toile et l'étape de crêpage de sorte que le rapport de traction SM/ST à sec de la bande séchée soit au maximum d'environ 1.

3. Procédé selon la revendication 1, comprenant en outre la régulation de la différence de vitesses jet/toile et l'étape de crêpage de sorte que le rapport de traction SM/ST à sec de la bande séchée soit au maximum d'environ 0,75.

4. Procédé selon la revendication 1, comprenant en outre la régulation de la différence de vitesses jet/toile et l'étape de crêpage de sorte que le rapport de traction SM/ST à sec de la bande séchée soit au maximum d'environ 0,5.

5. Procédé selon la revendication 1, dans lequel la différence de vitesses jet/toile est supérieure à environ 2,03 m/s (400 fpm).

6. Procédé selon la revendication 1, dans lequel la différence de vitesses jet/toile est supérieure à environ 2,23 m/s (450 fpm).

FIG. 1
FABRIC CREPED

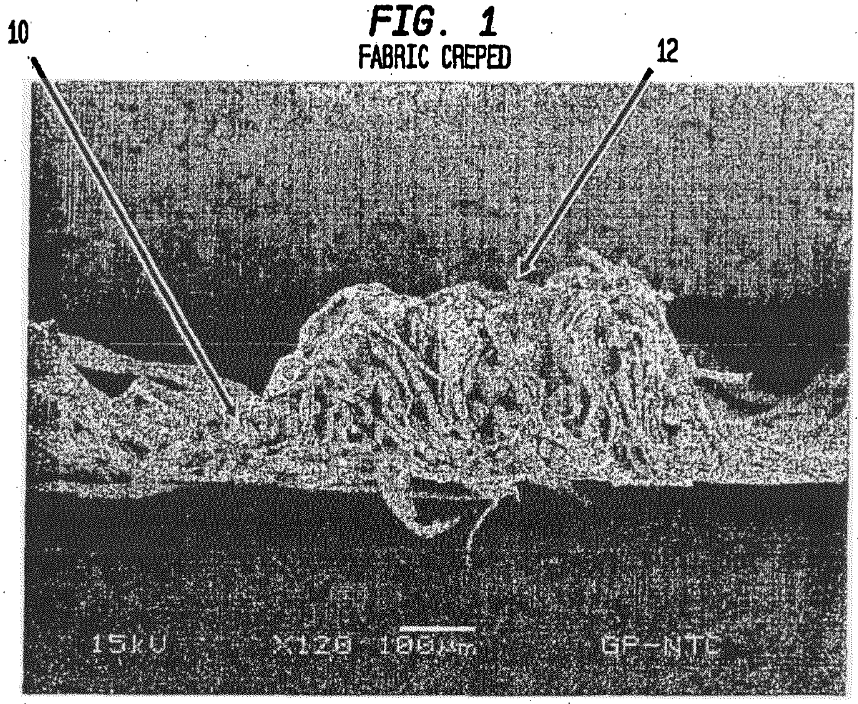


FIG. 2
FABRIC CREPED AND DRAWN

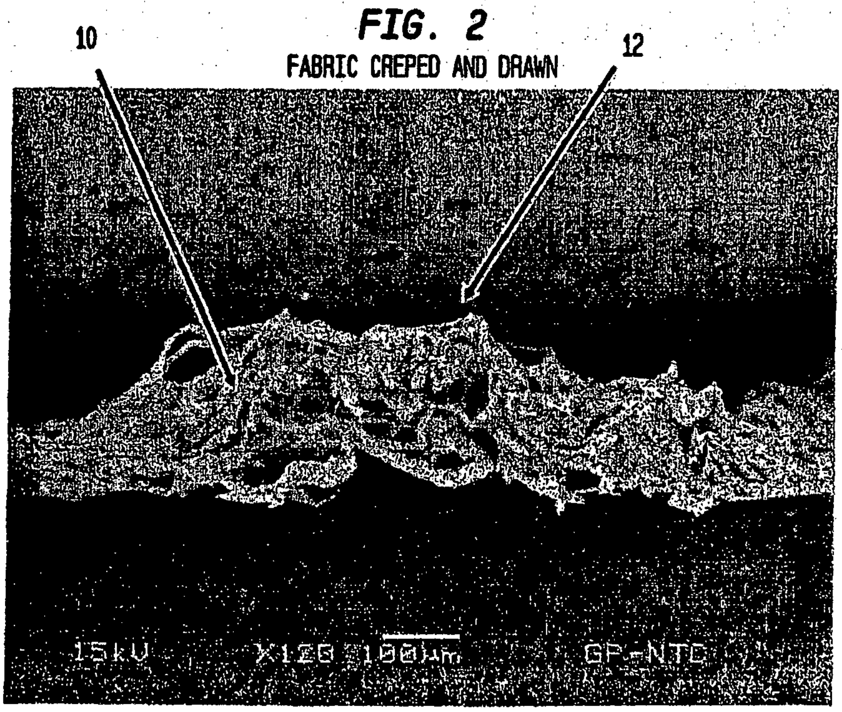


FIG. 3

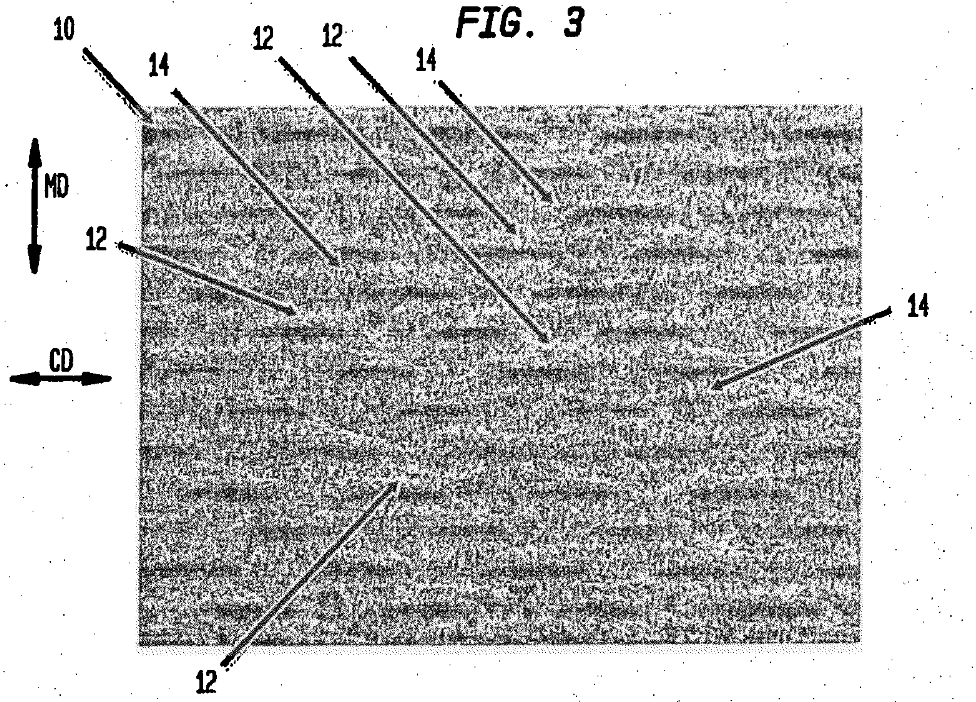


FIG. 4

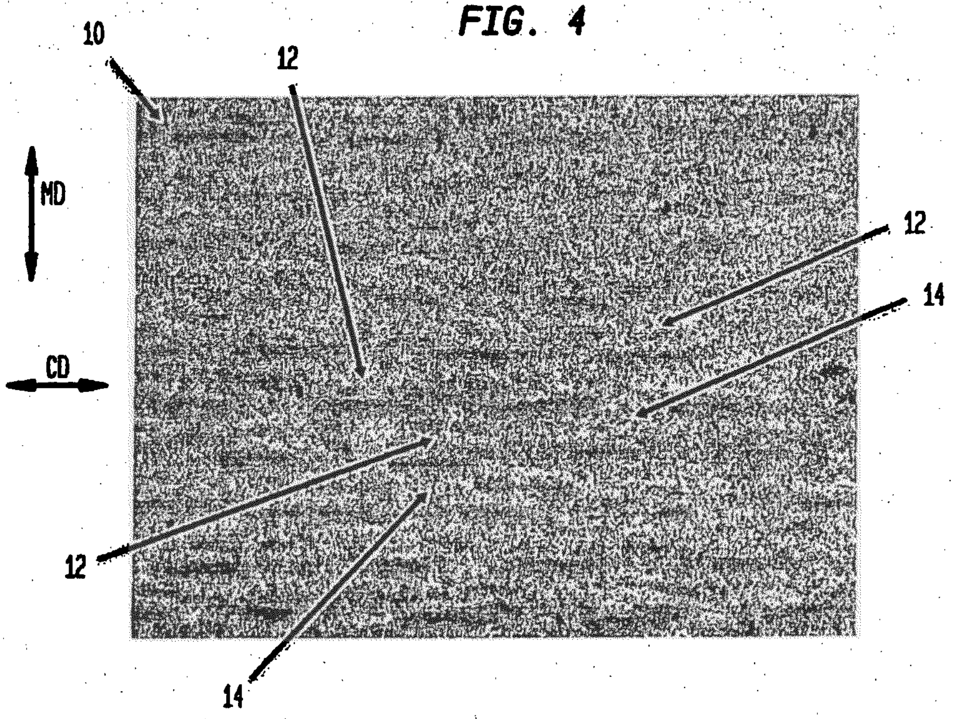


FIG. 5

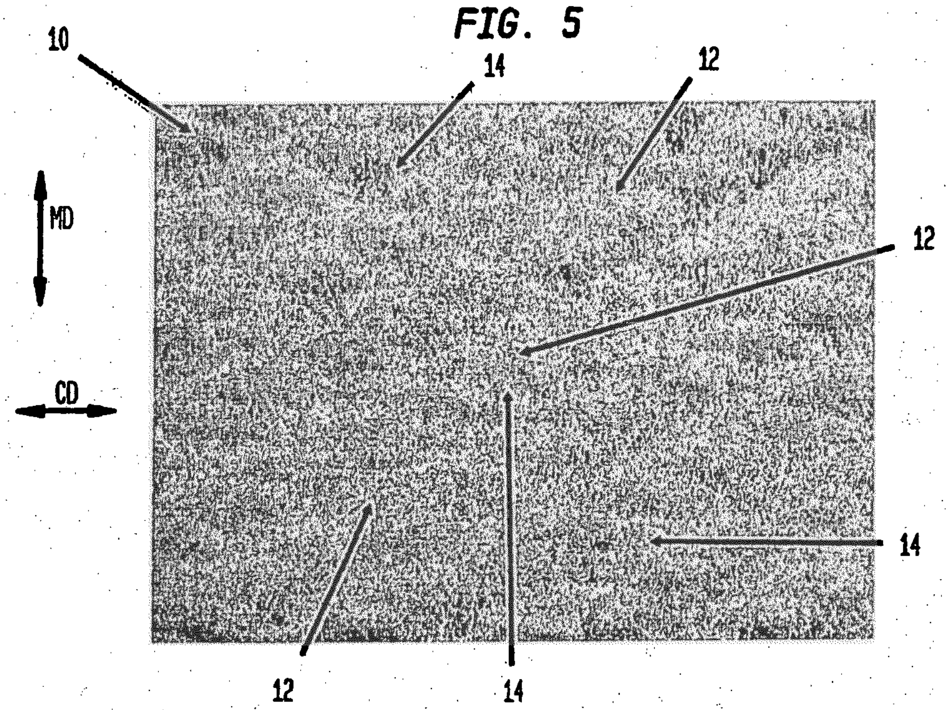


FIG. 6

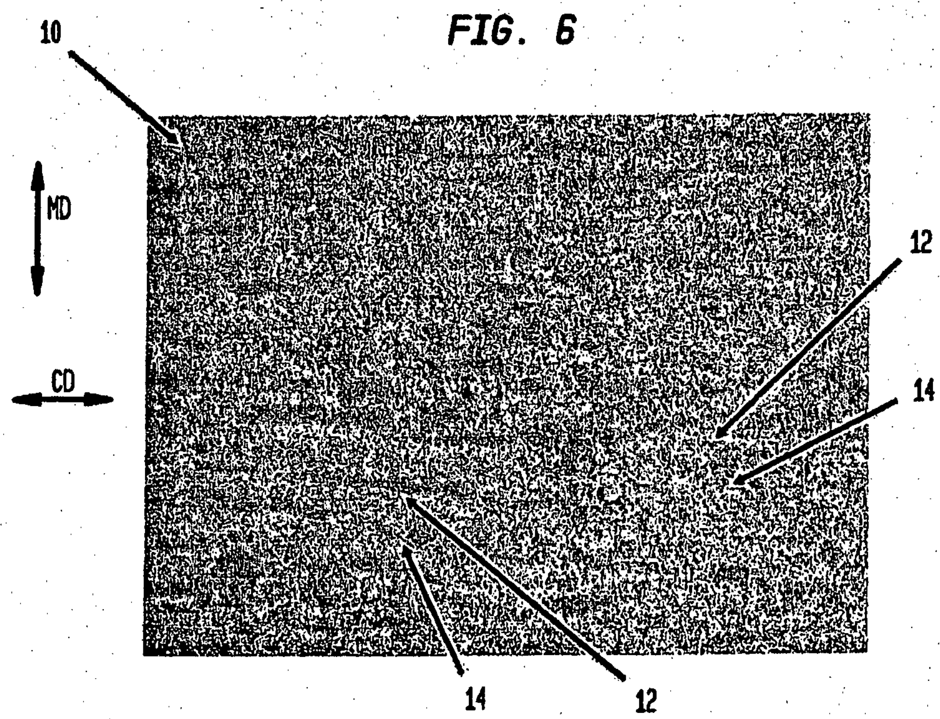


FIG. 7

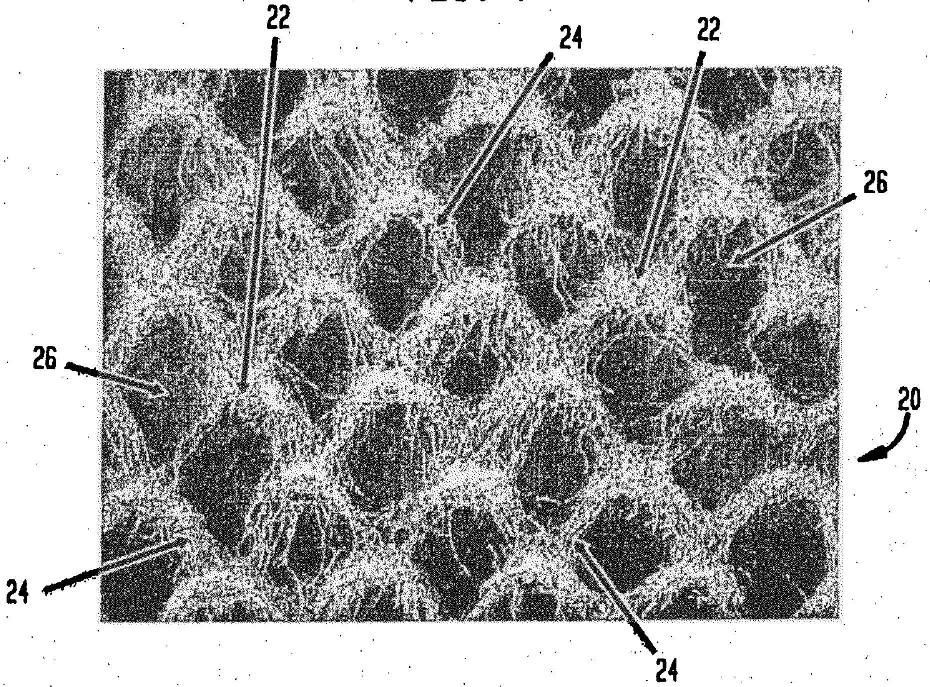


FIG. 8

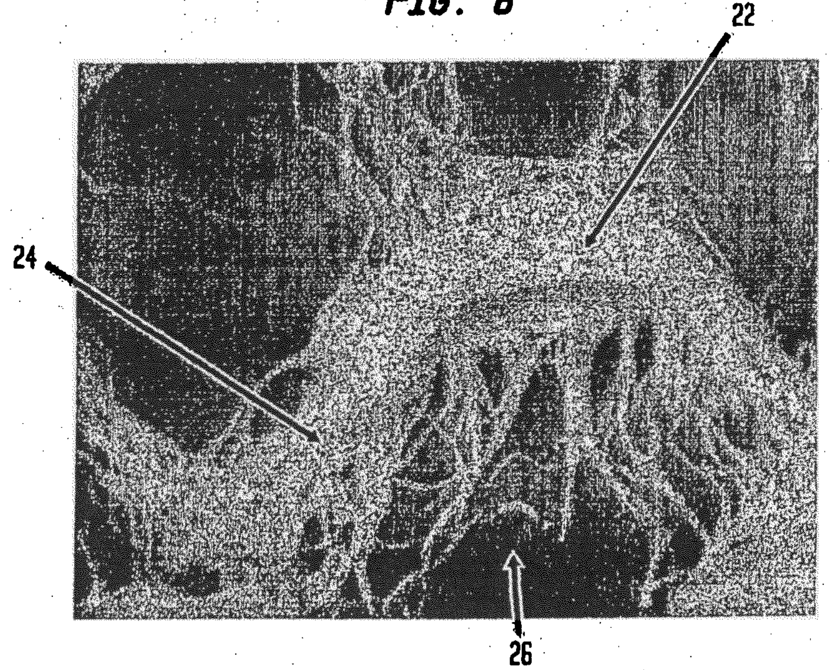


FIG. 9

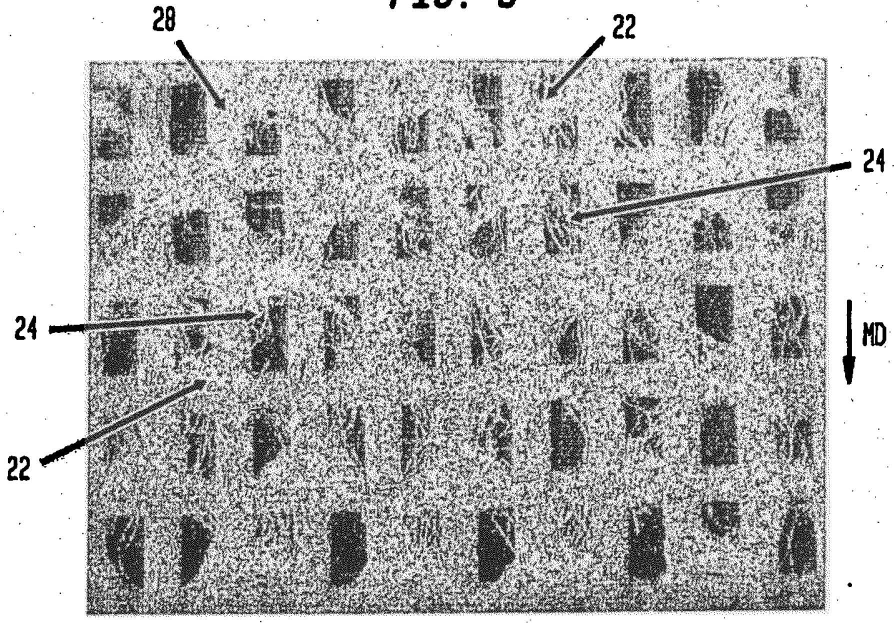


FIG. 10

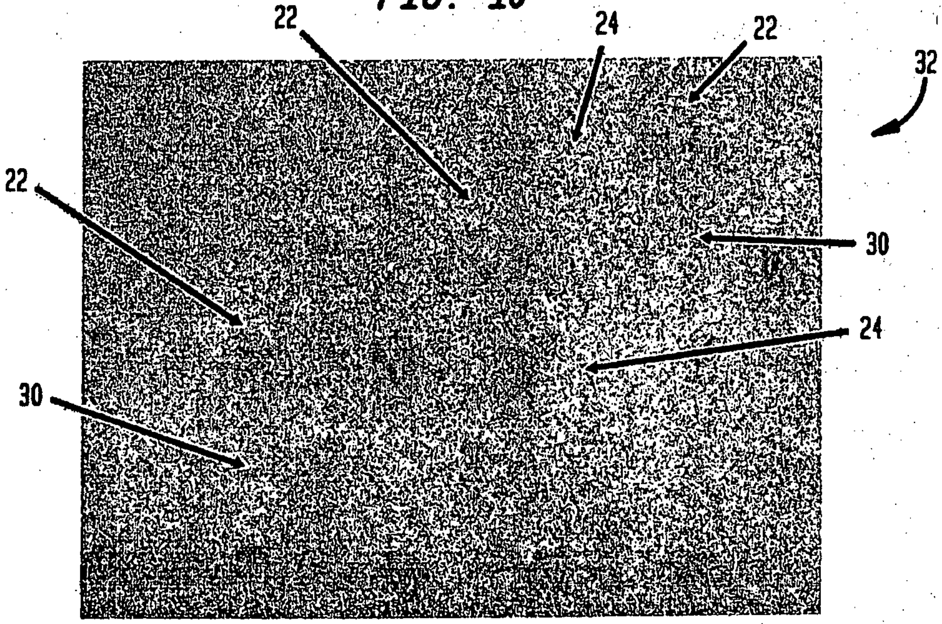


FIG. 11

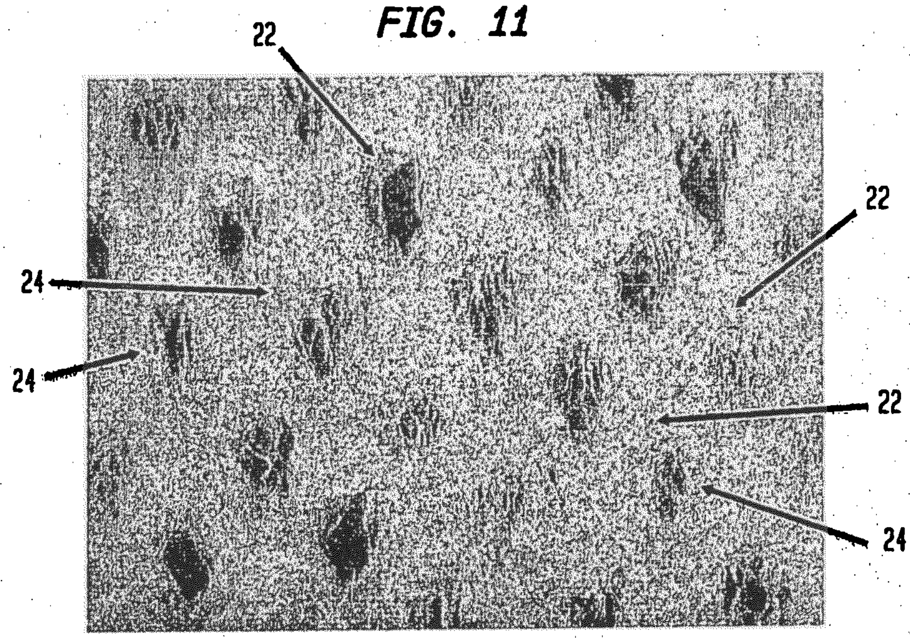


FIG. 12

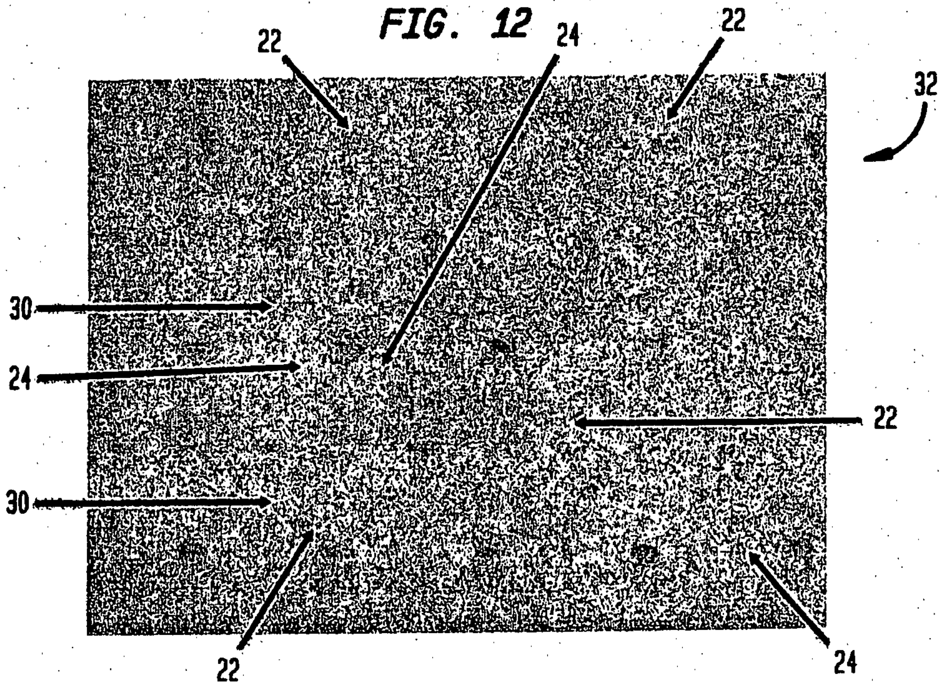


FIG. 13

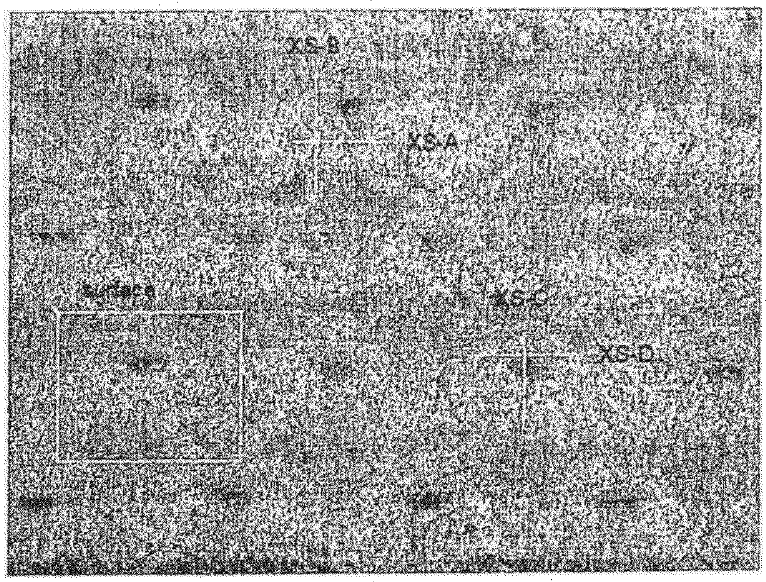


FIG. 14

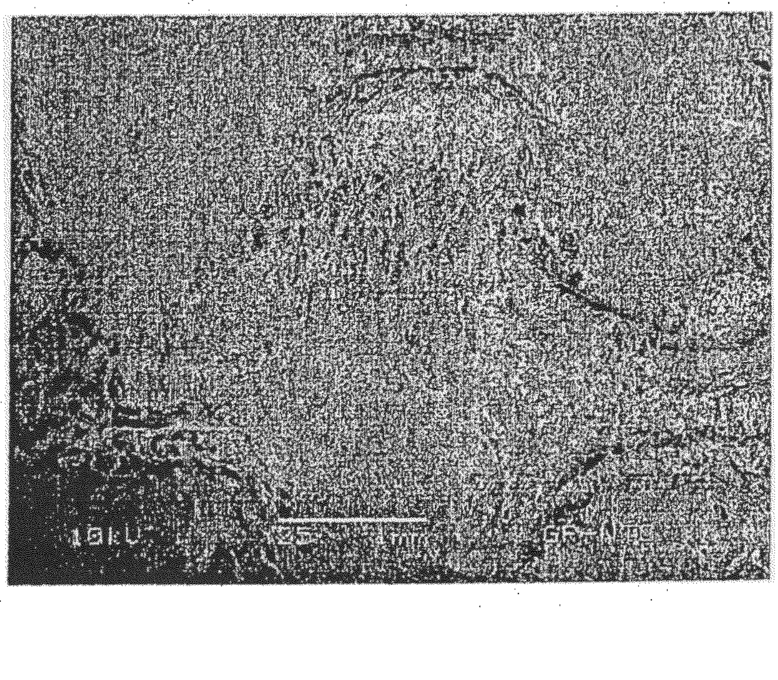


FIG. 15

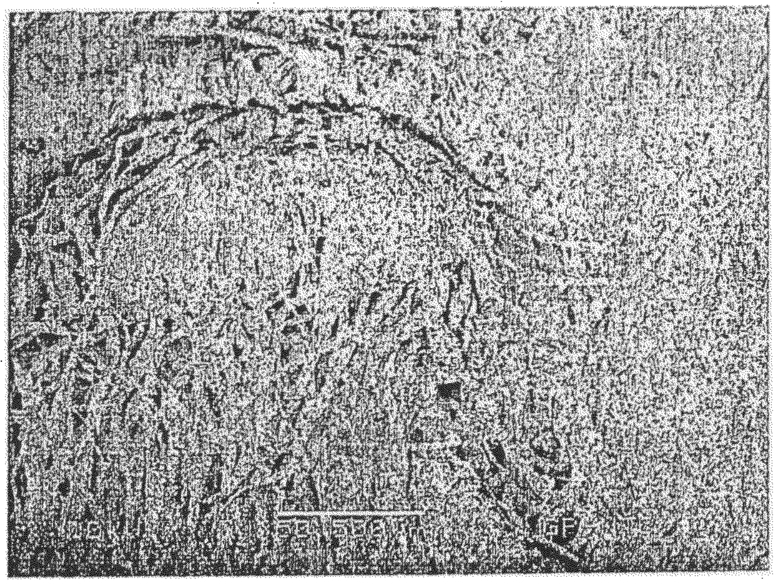


FIG. 16

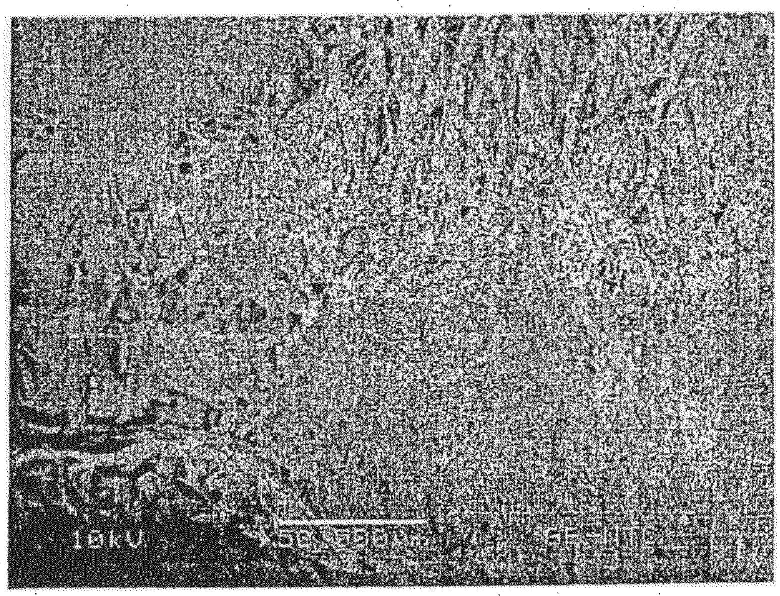


FIG. 17

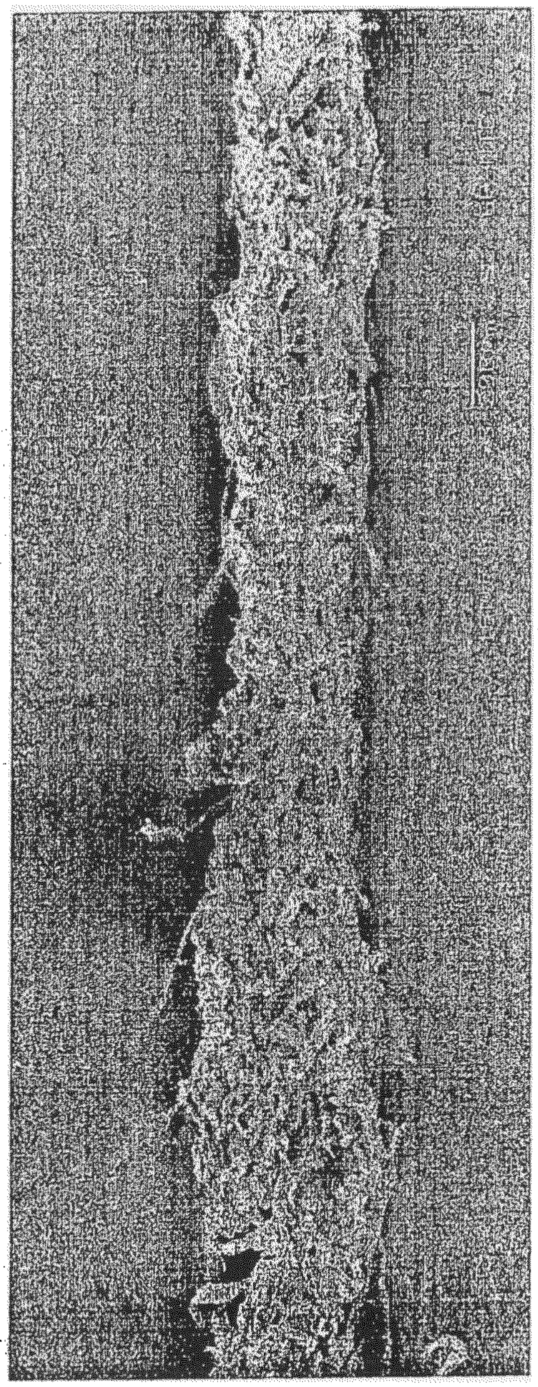
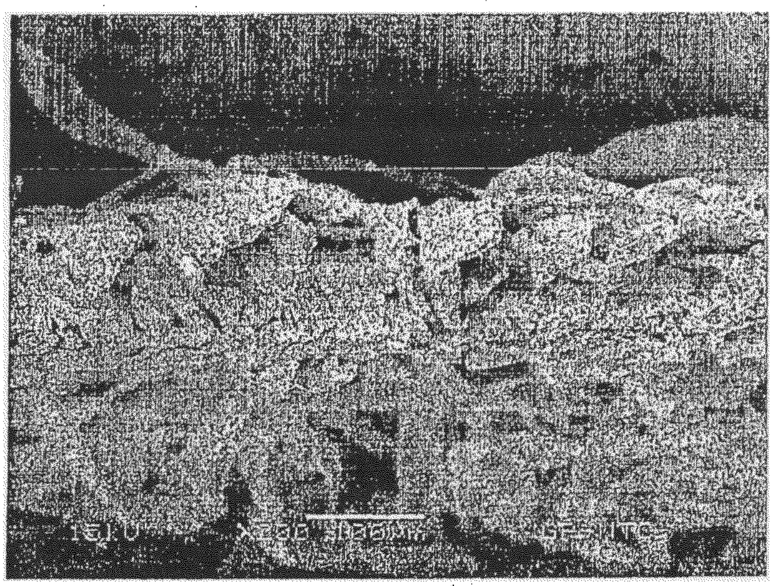


FIG. 18



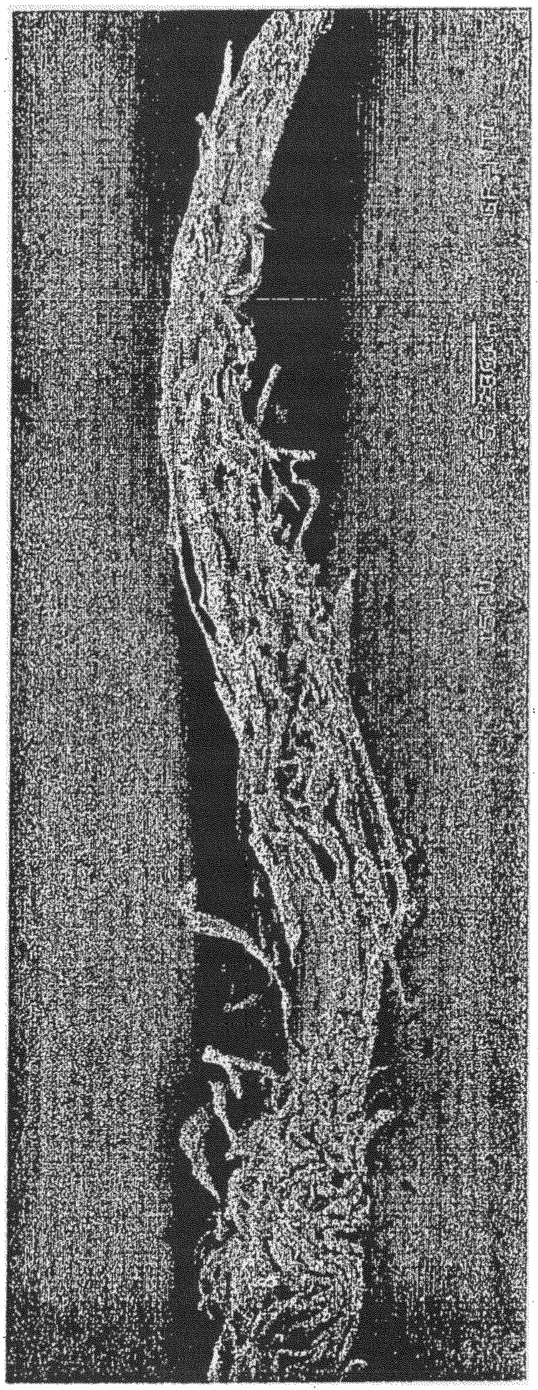
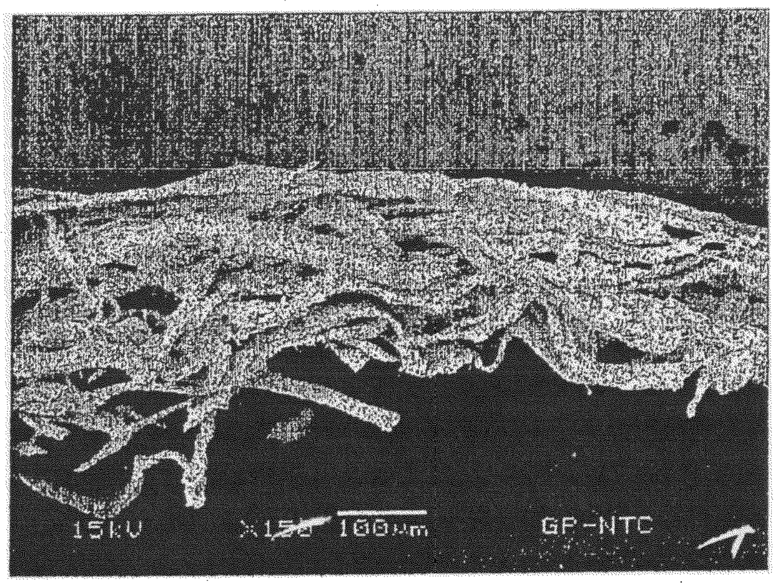


FIG. 19

FIG. 20



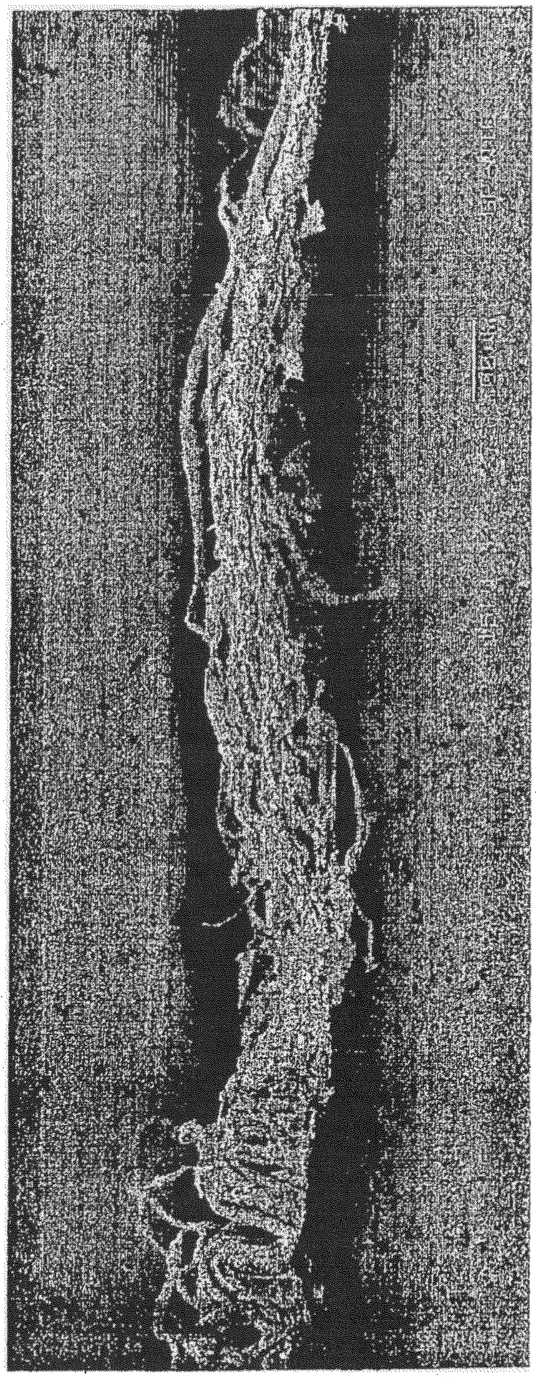


FIG. 21

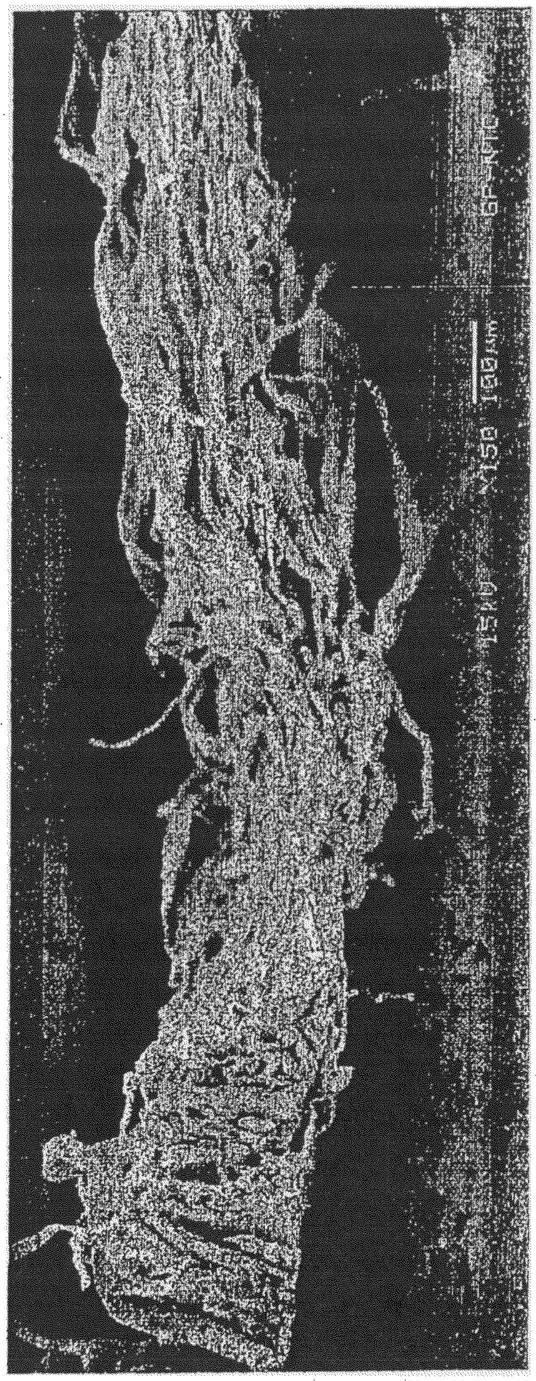


FIG. 22

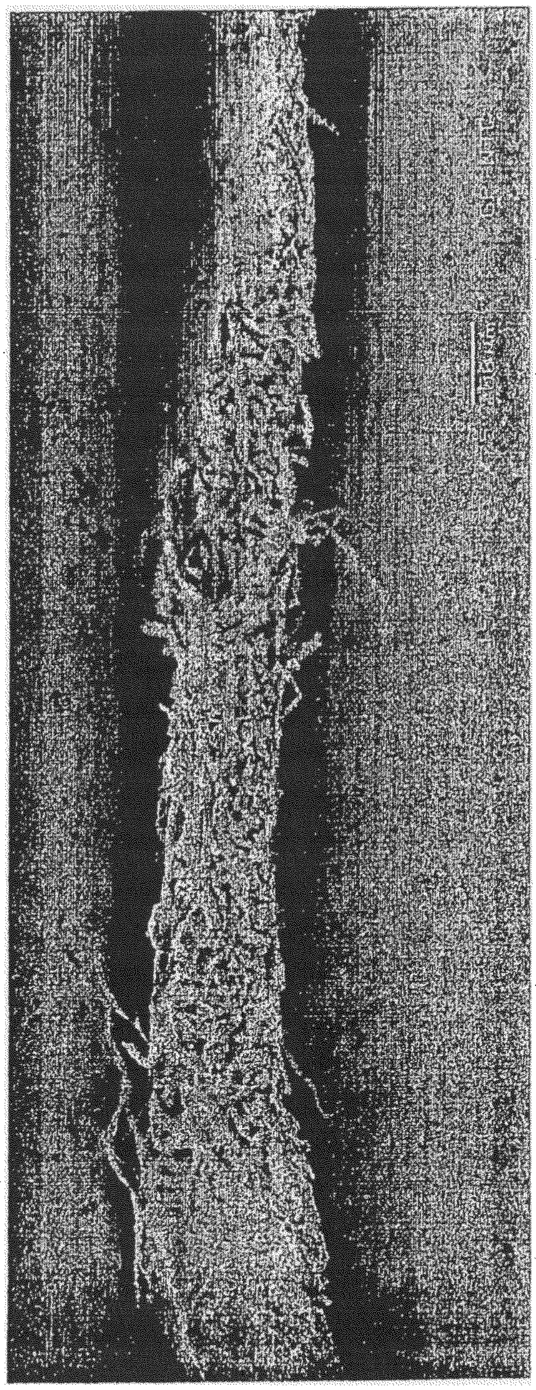
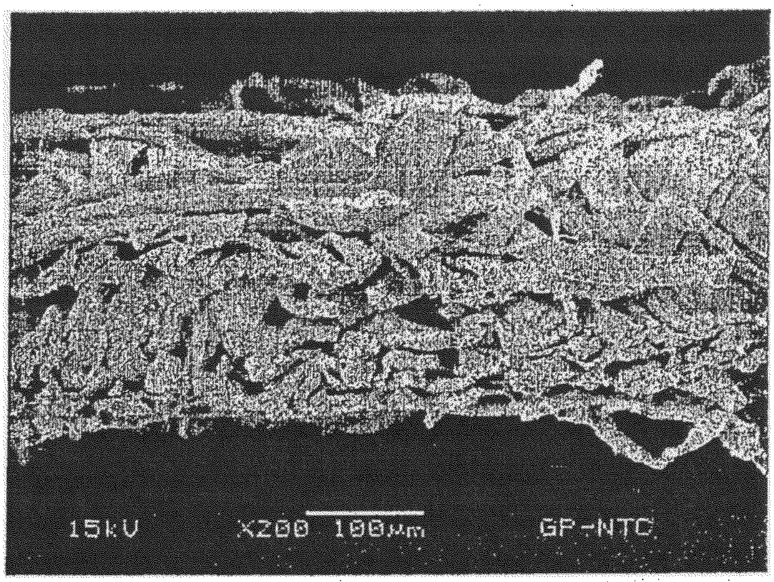


FIG. 23

FIG. 24



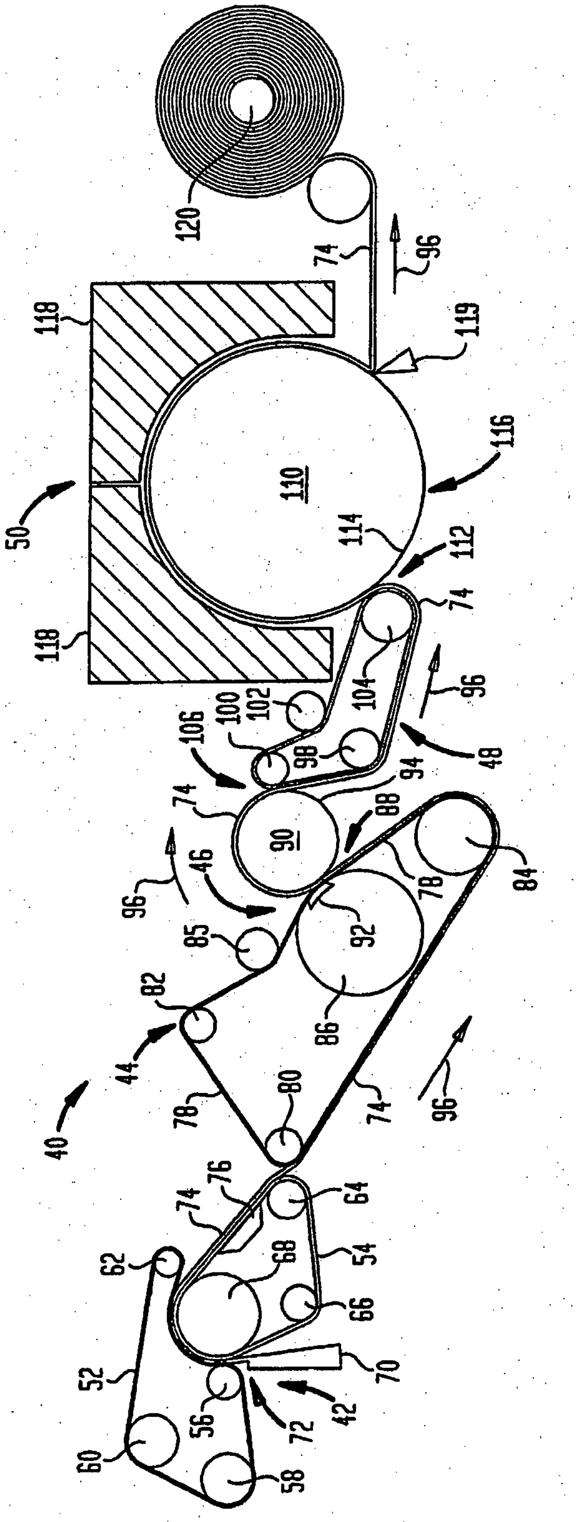

120
74
96
118
119
116
110
50
114
112
118
74
96
100
102
104
106
98
48
94
88
74
90
96
46
85
92
78
84
82
86
44
40
80
78
74
96
76
74
64
62
68
54
66
52
70
56
72
42
60
58

FIG. 25

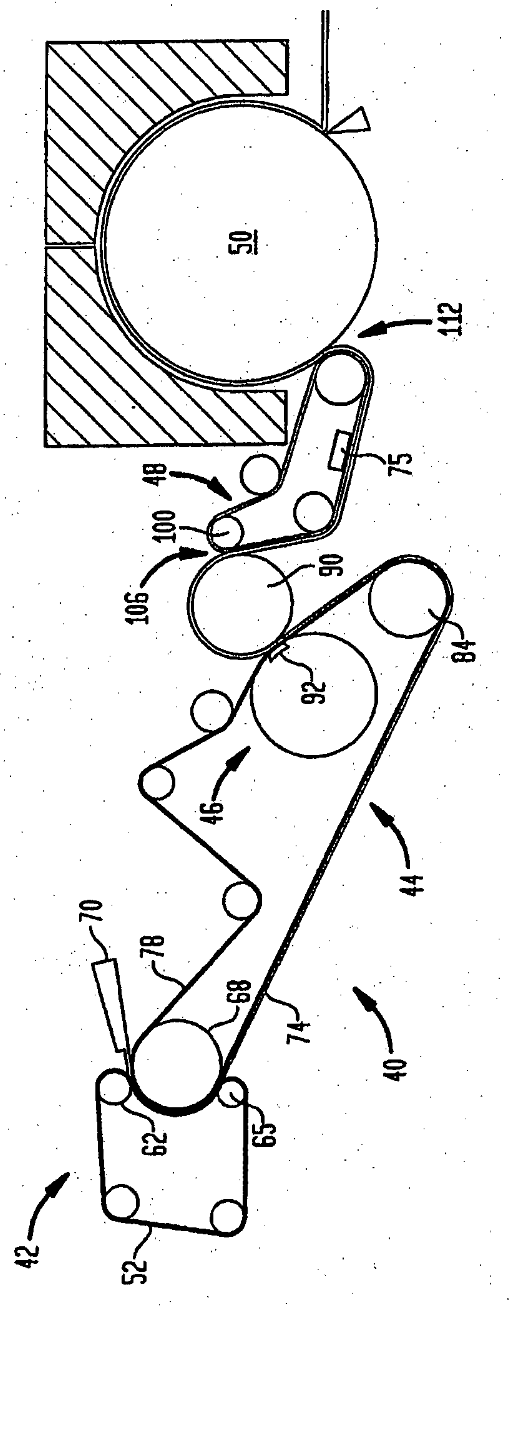


FIG. 26

FIG. 27

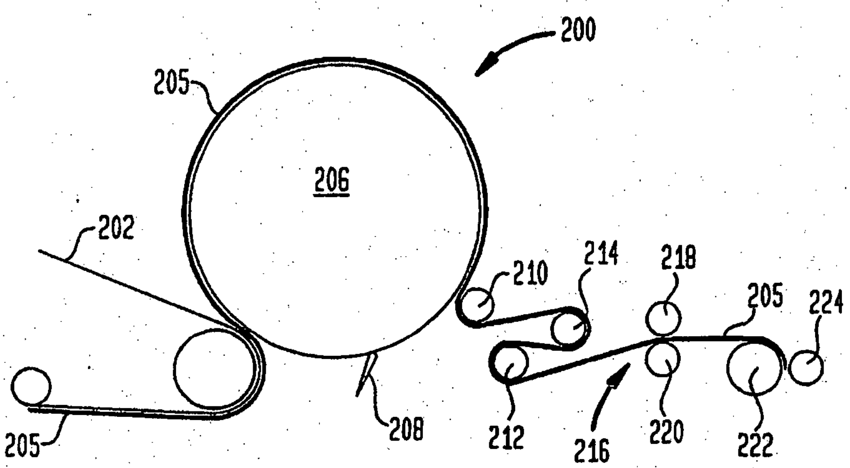


FIG. 28A

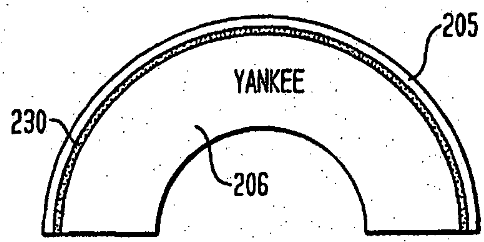


FIG. 28B

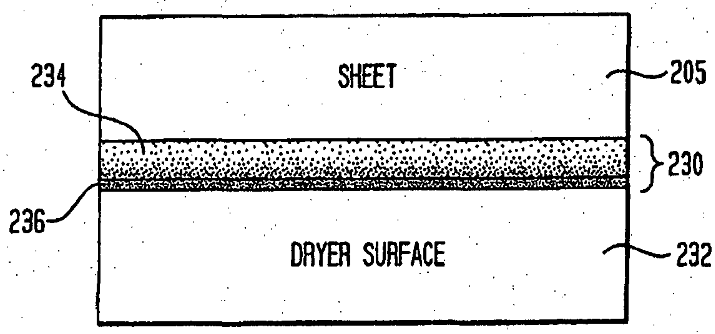


FIG. 29A

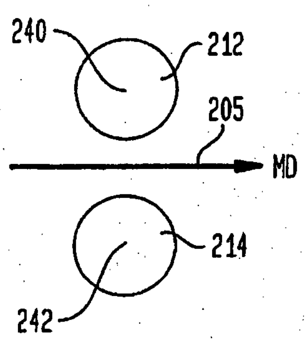


FIG. 29B

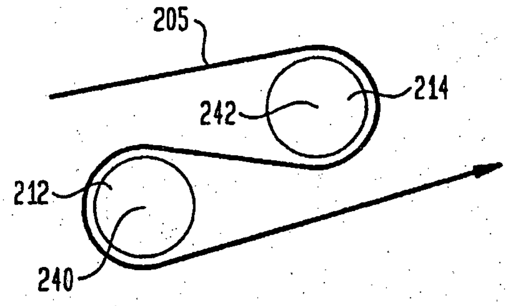


FIG. 30

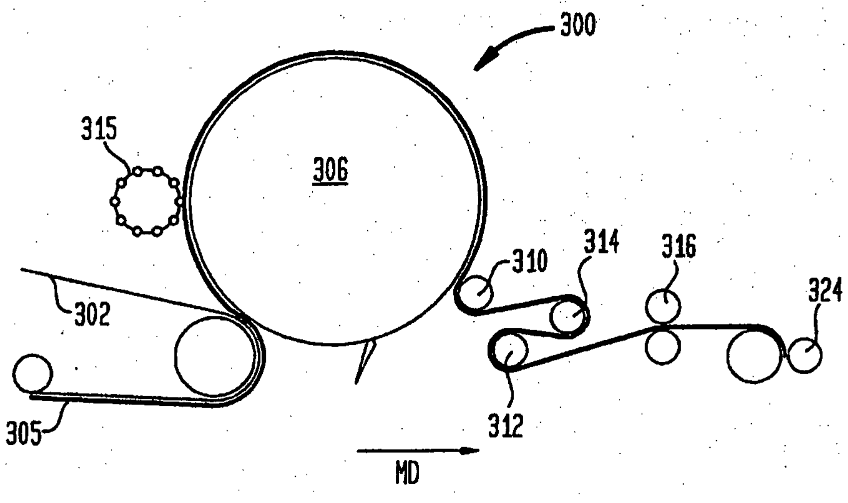
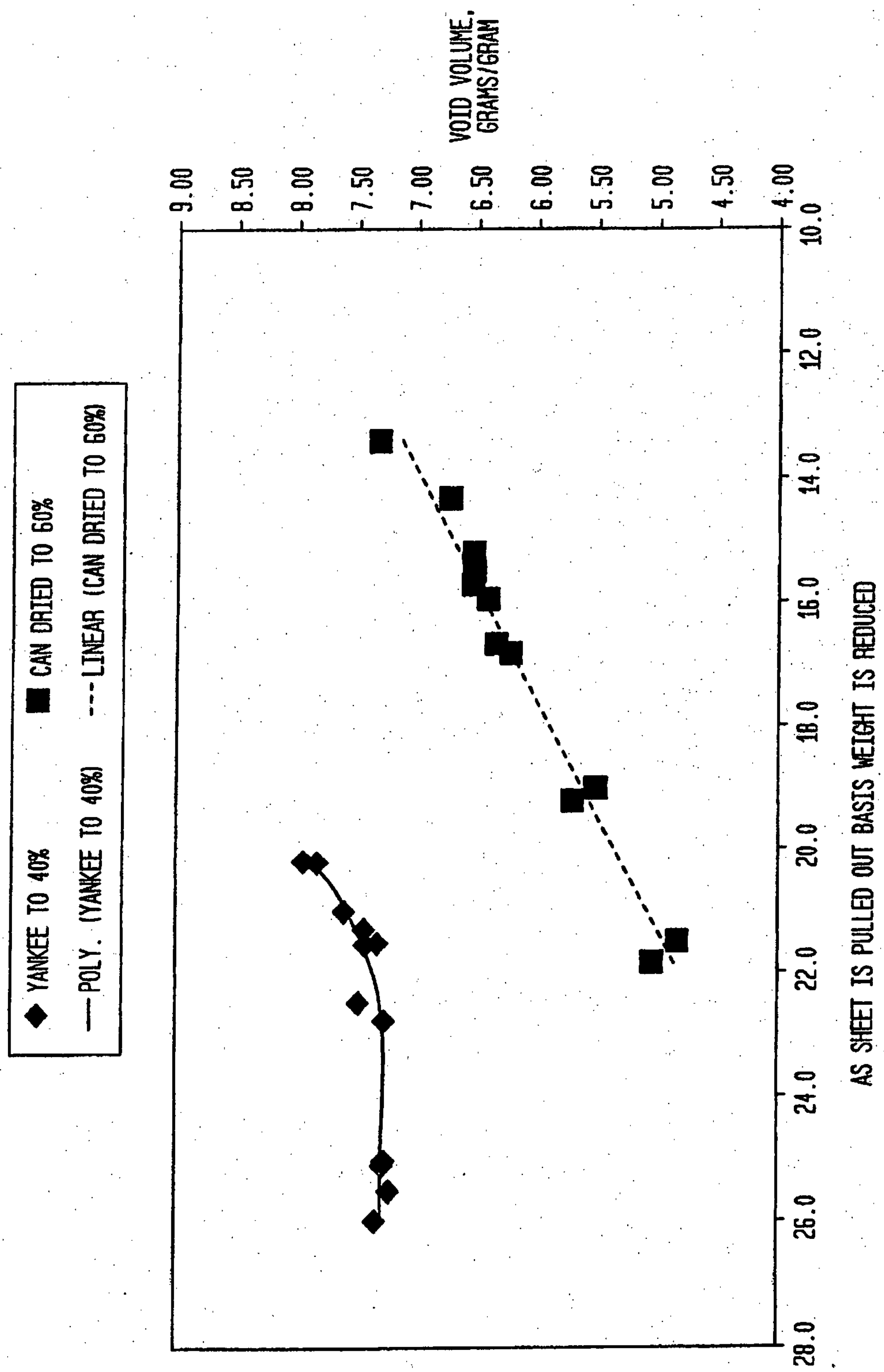


FIG. 31



YANKEE TO 40%
CAN DRIED TO 60%
POLY. (YANKEE TO 40%)
LINEAR (CAN DRIED TO 60%)
VOID VOLUME, GRAMS/GRAM
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
AS SHEET IS PULLED OUT BASIS WEIGHT IS REDUCED

FIG. 32

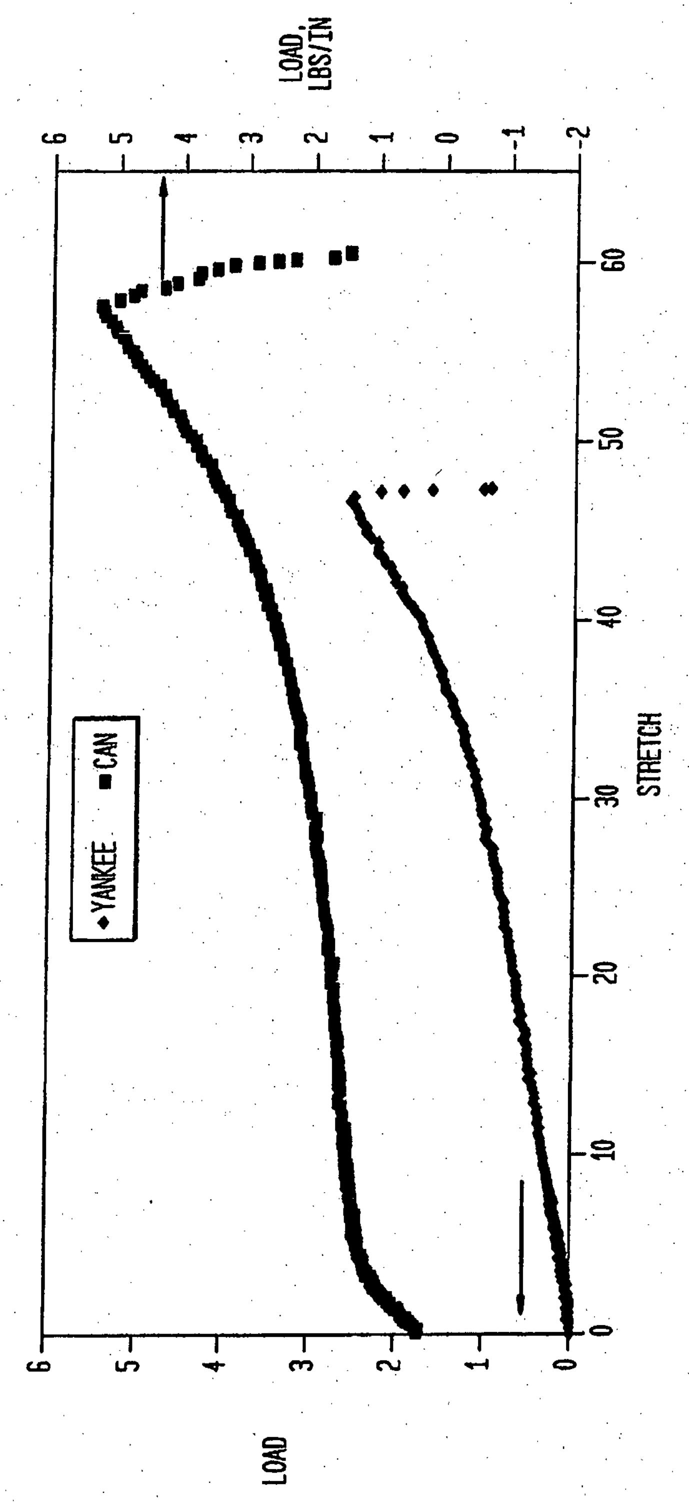

LOAD, LBS/IN
YANKEE
CAN
STRETCH
LOAD
0
10
20
30
40
50
60
6
5
4
3
2
1
0
-1
-2

FIG. 33

CAN DRIED FABRIC CREPE PRODUCT

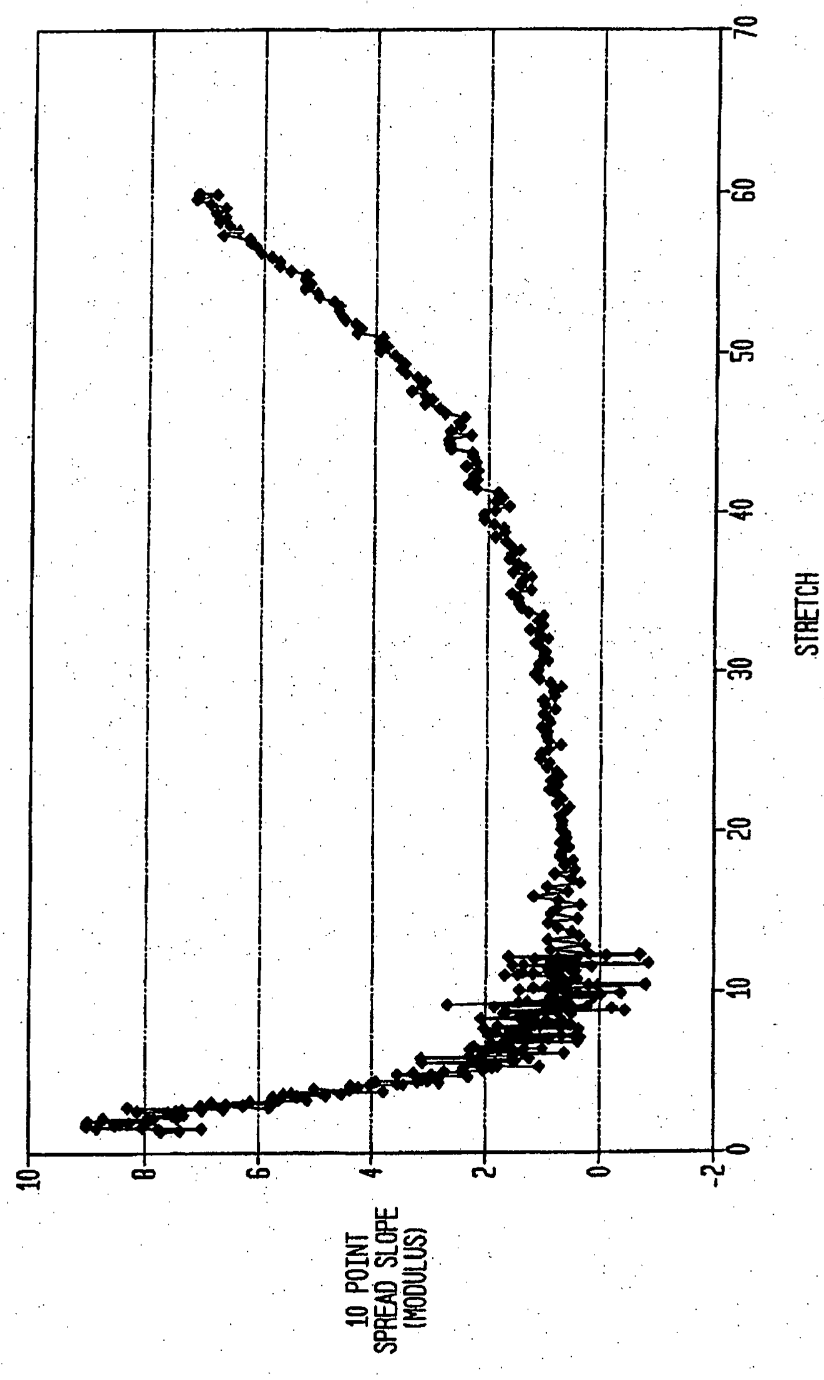


FIG. 34

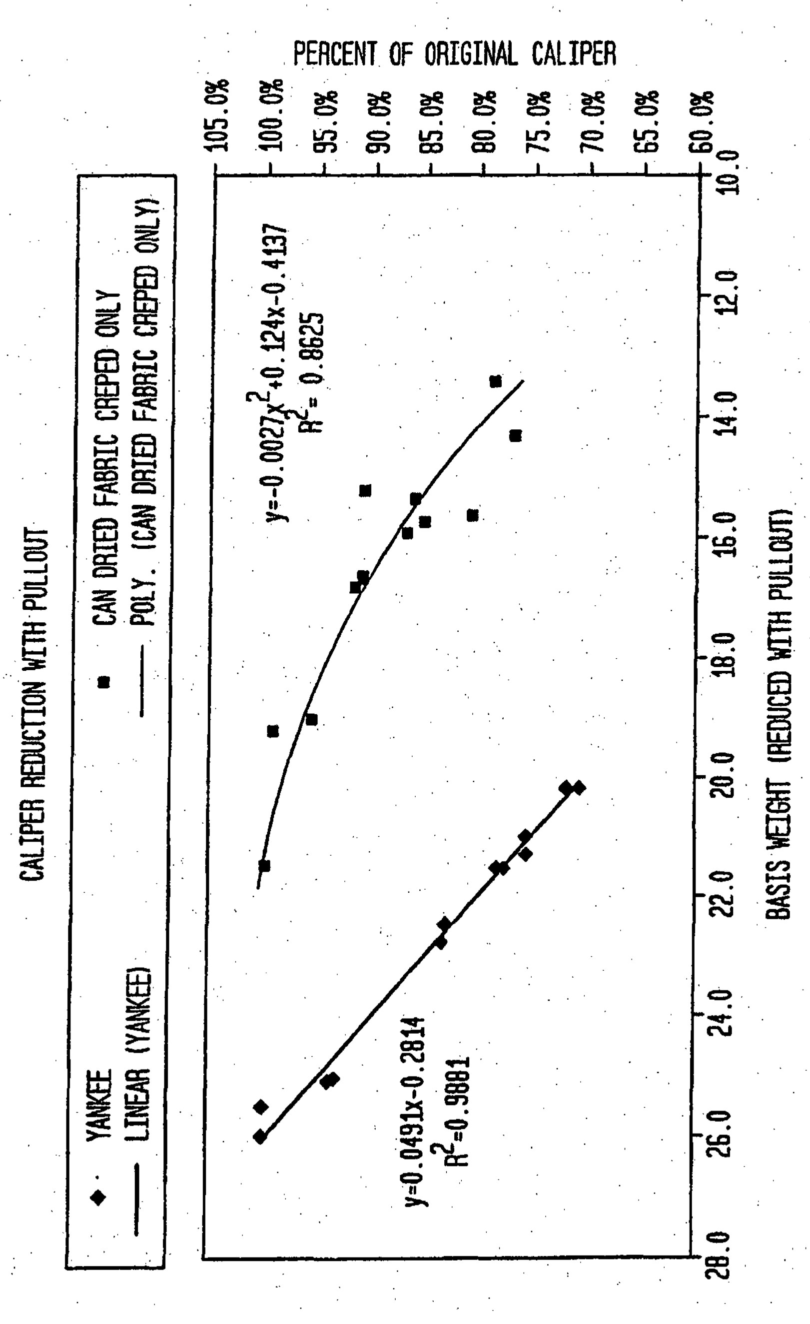

CALIPER REDUCTION WITH PULLOUT
YANKEE
LINEAR (YANKEE)
CAN DRIED FABRIC CREPED ONLY
POLY. (CAN DRIED FABRIC CREPED ONLY)
PERCENT OF ORIGINAL CALIPER
105.0%
100.0%
95.0%
90.0%
85.0%
80.0%
75.0%
70.0%
65.0%
60.0%
y=-0.0027x2+0.124x-0.4137
R2= 0.8625
y=0.0491x-0.2814
R2=0.9881
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
BASIS WEIGHT (REDUCED WITH PULLOUT)

FIG. 35

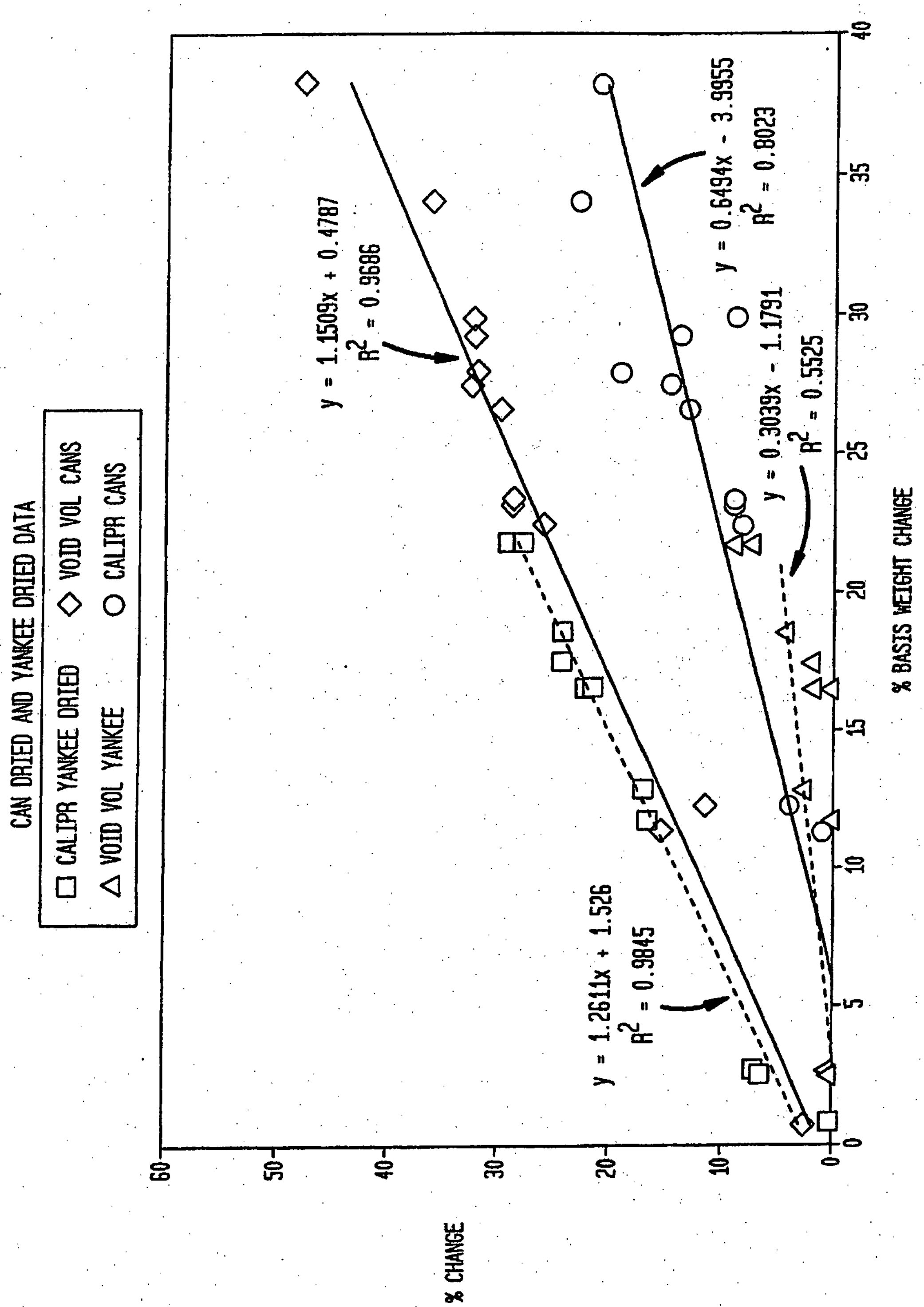

CAN DRIED AND YANKEE DRIED DATA
□ CALIPR YANKEE DRIED
◇ VOID VOL CANS
△ VOID VOL YANKEE
○ CALIPR CANS
y = 1.1509x + 0.4787
R2 = 0.9686
y = 0.6494x - 3.9955
R2 = 0.8023
y = 0.3039x - 1.1791
R2 = 0.5525
y = 1.2611x + 1.526
R2 = 0.9845
% CHANGE
% BASIS WEIGHT CHANGE
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40

FIG. 36

FABRIC COMPARISONS

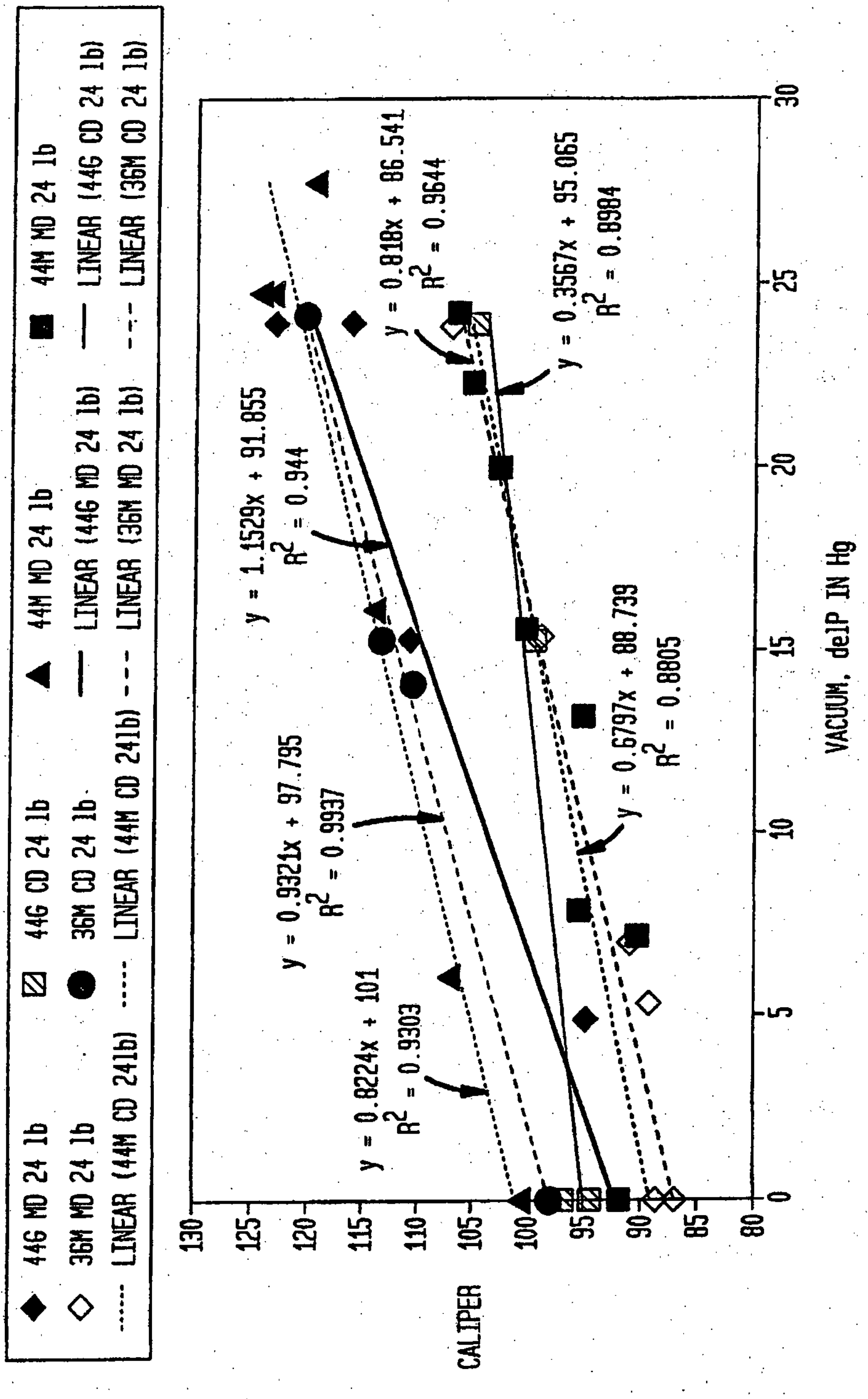


FIG. 37

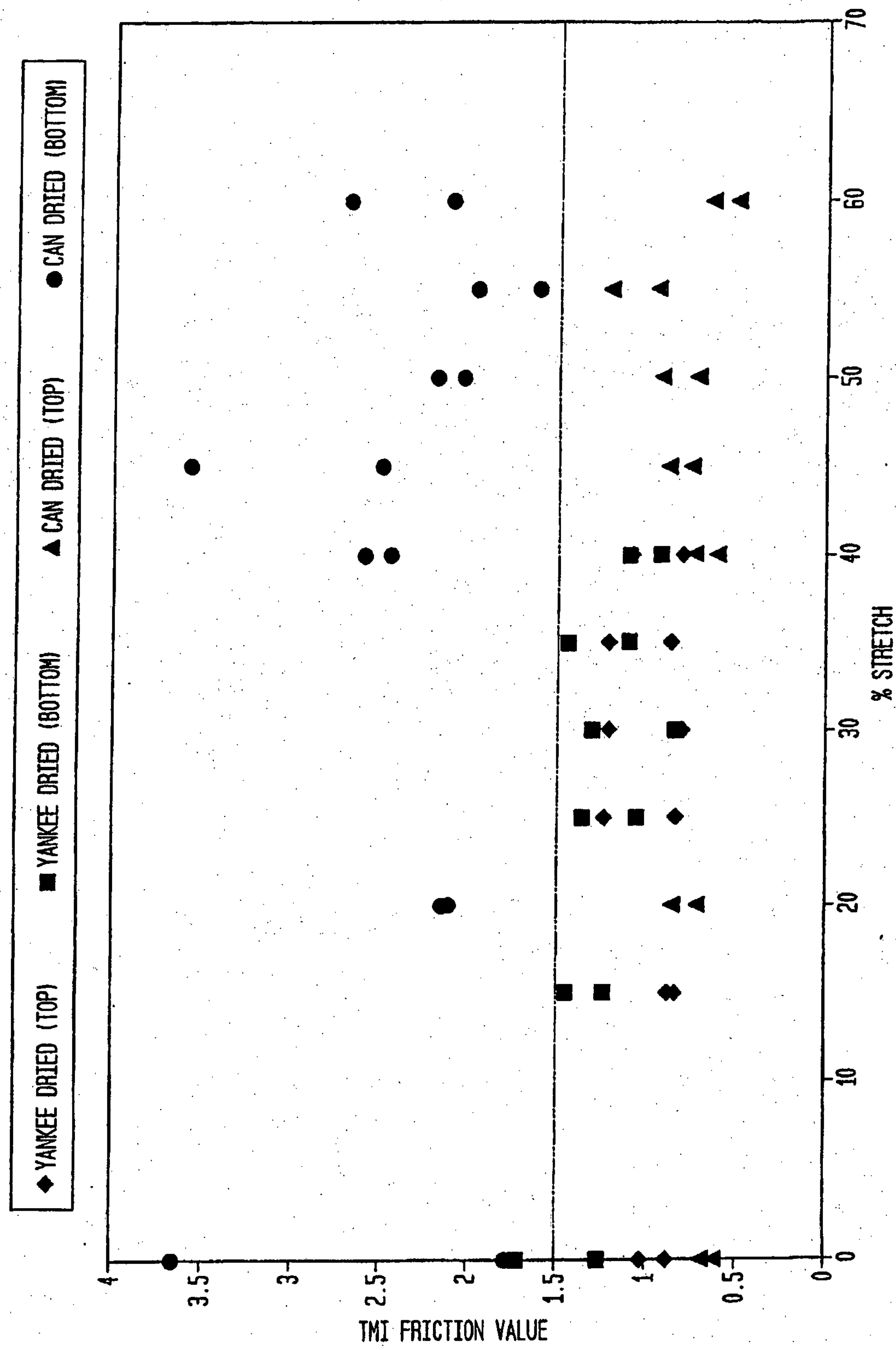

◆ YANKEE DRIED (TOP)
■ YANKEE DRIED (BOTTOM)
▲ CAN DRIED (TOP)
● CAN DRIED (BOTTOM)
TMI FRICTION VALUE
0
0.5
1
1.5
2
2.5
3
3.5
4
% STRETCH
0
10
20
30
40
50
60
70

FIG. 38

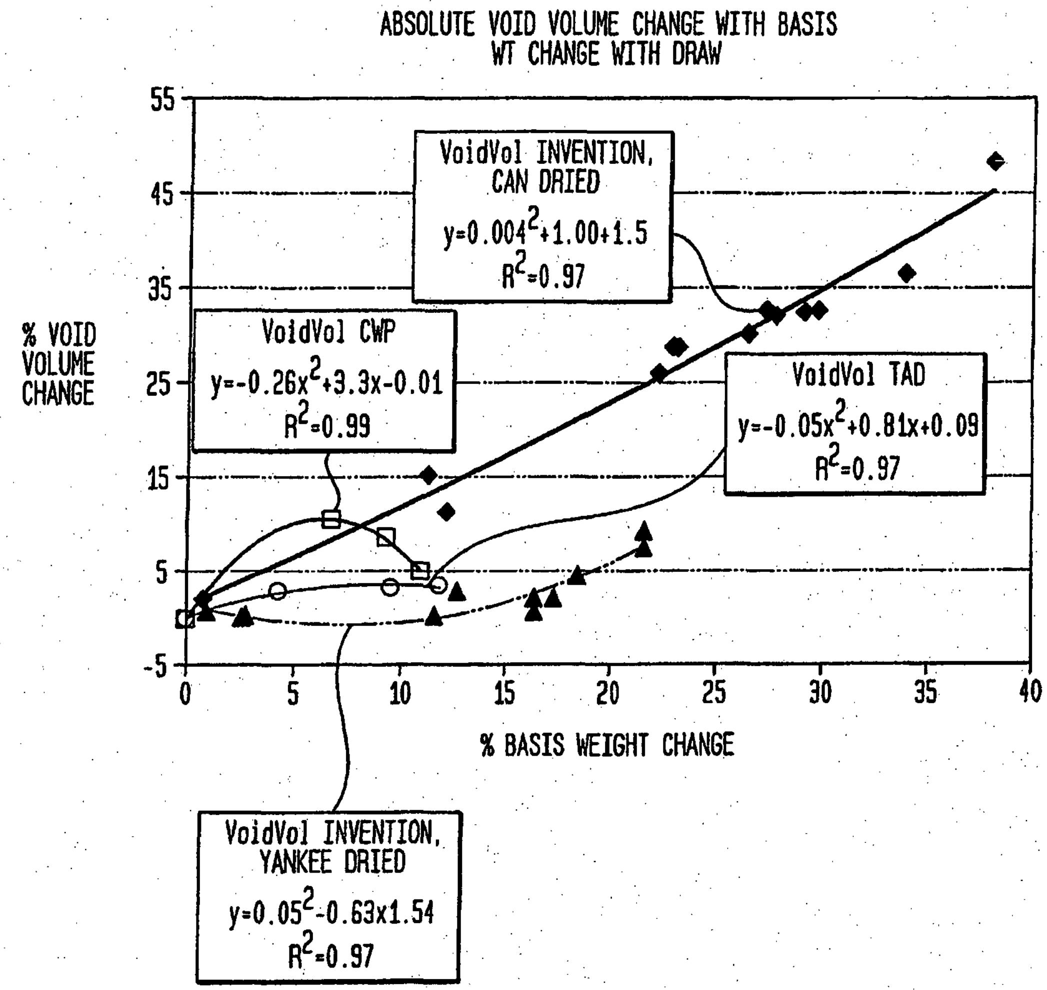
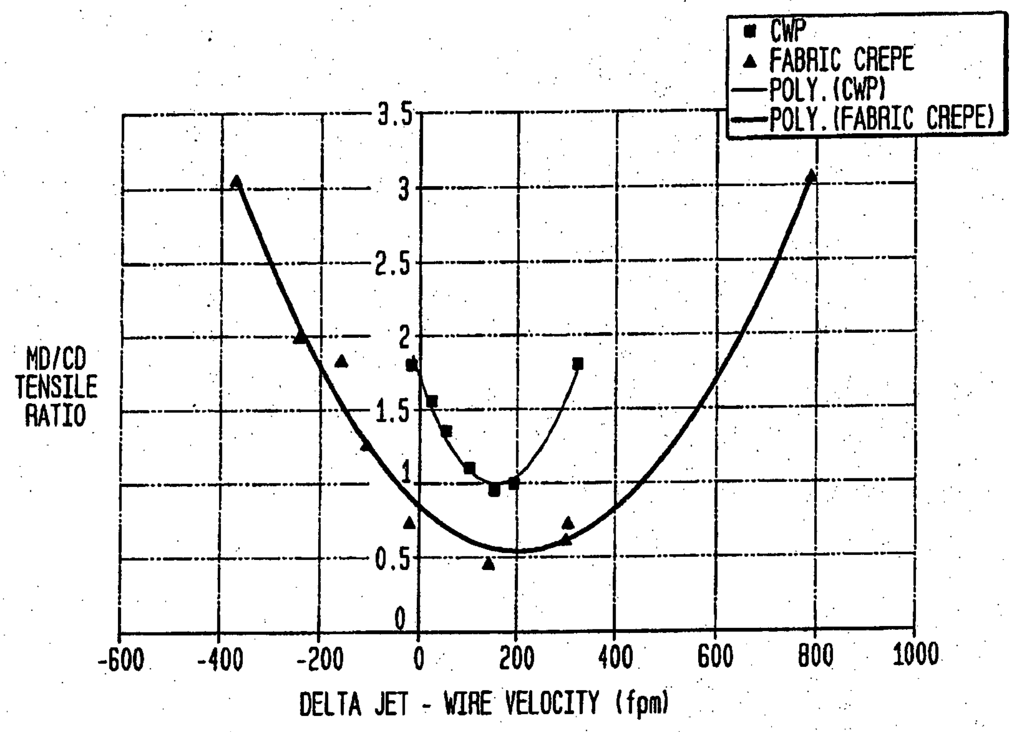

ABSOLUTE VOID VOLUME CHANGE WITH BASIS WT CHANGE WITH DRAW
% VOID VOLUME CHANGE
% BASIS WEIGHT CHANGE
55
45
35
25
15
5
-5
0
5
10
15
20
25
30
35
40
VoidVol INVENTION, CAN DRIED
y=0.004²+1.00+1.5
R²=0.97
VoidVol CWP
y=-0.26x²+3.3x-0.01
R²=0.99
VoidVol TAD
y=-0.05x²+0.81x+0.09
R²=0.97
VoidVol INVENTION, YANKEE DRIED
y=0.05²-0.63x1.54
R²=0.97

FIG. 39


CWP
FABRIC CREPE
POLY.(CWP)
POLY.(FABRIC CREPE)
MD/CD TENSILE RATIO
3.5
3
2.5
2
1.5
1
0.5
0
-600
-400
-200
0
200
400
600
800
1000
DELTA JET - WIRE VELOCITY (fpm)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

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714616/DO

ELJÁRÁS SZÖVETKREPPELT, NEDVSZÍVÓ CELLULÓZLAP ELŐÁLLÍTÁSÁRA

SZABADALMI IGÉNYPONTOK

1. Eljárás szövetkreppelt, nedvszívó cellulózlap (74) előállítására, amely eljárás magában foglalja, hogy:

(a) a papírgyártási pép egy sugarát lapképző szitahuzalra (52) juttatjuk, amely sugárnak van egy sugársebessége, a lapképző szitahuzal (52) pedig lapképző-szitahuzal sebességgel mozog, és a sugársebesség mínusz a lapképző-szitahuzal sebesség számított értékére sugár/szitahuzal sebességkülönbségként hivatkozunk;

(b) tömörítéssel víztelenítjük a papírgyártási pépet naszcens papírszövet (74) létrehozása céljából;

(c) felvisszük a naszcens papírszövetet (74) egy átviteli felületre (94), amely egy átviteli-felület sebességgel mozog;

(d) a naszcens papírszövetet (74) körülbelül 30-60 százalékos konzisztencián szövetkreppeléssel leszedjük az átviteli felületről (94) kreppelő szövetet (48) használva, amely szövet egy szövetkreppelési sebességgel halad, amely szövetkreppelési sebesség kisebb, mint az átviteli-felület sebesség, a szövetkreppelési lépés egy, az átviteli felület (94) és a kreppelő szövet (48) között határolt szövetkreppelési hengerrésben (106) nyomás alatt történik, és a szövetmintát, a hengerrés paramétereit, a sebességkülönbséget, valamint a papírszövet konziszteciáját úgy választjuk meg, hogy amikor a naszcens papírszövetet (74) lekreppeljük az átviteli felületről (94), és újra eloszlatjuk a kreppelő szöveten (48), olyan kreppelt papírszövet (74) alakuljon ki, amelynek hálószerkezete több, különböző helyi rizsmasúlyú, egymással összekapcsolt területtel rendelkezik, beleértve legalább

(i) több, nagy helyi rizsmasúlyú, rostban gazdag területet (12), amelyeket

(ii) több, kis helyi rizsmasúlyú, összekötő terület (14) kapcsol össze;

(e) szárítjuk a kreppelt papírszövetet (74);

azzal jellemezve, hogy az eljárás tartalmazza továbbá a következő lépést:

(f) úgy szabályozzuk a sugár/szitahuzal sebességkülönbséget és a szövetkreppelési lépést, beleértve a szövet kiválasztását, hogy a rostban gazdag területek (12) irányultsága keresztirányban (CD) rézsútos, a szárított papírszövetben (74) a gépiránybeli és a keresztiránybeli (MD/CD) száraz szakítószilárdságnak az egymáshoz viszonyított aránya körülbelül legfeljebb 1,5 azzal a kikötéssel, hogy a sugár/szitahuzal sebességkülönbség nagyobb, mint körülbelül 1,78 m/s (350 láb/perc).

2. Az 1. igénypont szerinti eljárás, amely magában foglalja továbbá, hogy úgy

szabályozzuk a sugár/szitahuzal sebességkülönbséget és a szövetkreppelési lépést, hogy a szárított papírszövetben a száraz MD/CD szakítószilárdsági arány körülbelül legfeljebb 1.

3. Az 1. igénypont szerinti eljárás, amely magában foglalja továbbá, hogy úgy szabályozzuk a sugár/szitahuzal sebességkülönbséget és a szövetkreppelési lépést, hogy a szárított papírszövetben a száraz MD/CD szakítószilárdsági arány körülbelül legfeljebb 0,75.

4. Az 1. igénypont szerinti eljárás, amely magában foglalja továbbá, hogy úgy szabályozzuk a sugár/szitahuzal sebességkülönbséget és a szövetkreppelési lépést, hogy a szárított papírszövetben a száraz MD/CD szakítószilárdsági arány körülbelül legfeljebb 0,5.

5. Az 1. igénypont szerinti eljárás, amelyben a sugár/szitahuzal sebességkülönbség nagyobb, mint körülbelül 2,03 m/s (400 láb/perc).

6. Az 1. igénypont szerinti eljárás, amelyben a sugár/szitahuzal sebességkülönbség nagyobb, mint körülbelül 2,23 m/s (450 láb/perc).

(A meghatalmazott)

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