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(54) Title: FIBROUS STRUCTURE AND PROCESS FOR MAKING SAME

(57) Abstract: Through-air dried ("TAD") fibrous structures, especially TAD fibrous structures incorporated into sanitary tissue products, that comprise a short fiber furnish having a length of from about 0.4 mm to about 1.2 mm and a low coarseness of from about 3.0 mg/100 m to about 7.5 mg/100 m, and a physical property ingredient selected from the group consisting of permanent wet strength resins, chemical softeners and mixtures thereof, and processes for making such TAD fibrous structures are provided.

FIBROUS STRUCTURE AND PROCESS FOR MAKING SAME

FIELD OF THE INVENTION

The present invention relates to fibrous structures, especially TAD ("TAD") fibrous structures incorporated into sanitary tissue products such as facial tissue, toilet tissue and paper towels, that comprise a short fiber furnish comprising a short fiber having a length of from about 0.4 mm to about 1.2 mm and a coarseness of from about 3.0 mg/100 m to about 7.5 mg/100 m, and processes for making such fibrous structures.

BACKGROUND OF THE INVENTION

Typically, fibrous structures used for sanitary tissue products contain two or more fiber furnishes. Such fibrous structures typically contain one furnish comprised of relatively long fibers, i.e. fibers with length-weighted average fiber length exceeding about 2 mm. This furnish is intended as reinforcement or strength generation within the sanitary tissue products. Additionally, the fibrous structures typically further comprise at least one relatively short fiber furnish, i.e. fibers having a fiber length less than about 1.2 mm. These short fibers improve the softness of the sanitary tissue products since they are relatively unbonded. The unbonded fibers allow free ends, which impart a velvety smoothness to the structure. See US Patent No. 4,300,981 to Carstens incorporated herein by reference for a disclosure of such velvety structures.

It is well known to those skilled in the art that the use of the short fibers is limited however from the point of view that a certain minimum average fiber length of that furnish is required and from the point of view that there is a maximum rate of inclusion of that furnish relative to the longer-fibered furnish or furnishes used in the sanitary tissue paper structure. This limitation is due to the fact that strength is lost. A certain amount of strength is necessary to be present in the product for the manufacturer to be able to handle the web which ultimately is converted into the sanitary tissue product. It is also necessary that the user of the end product be provided with a certain amount of strength to prevent/inhibit fingers poking through the product during use for example.

This problem with strength development is heightened when the tissue paper product is made by the so-called TAD papermaking process. This is because strength development is improved when the tissue paper web is pressed against the surface of a Yankee dryer. In some TAD processes, this pressing is changed from pressing over 100% of the area, typical of conventional non-TAD processes, to less than 50%, more preferably even less than 40% of the surface. While the strength development is surprisingly good, it necessarily suffers relative to conventional web making. Furthermore in some TAD processes, the Yankee dryer has been eliminated completely which obviously totally eliminates this means of strength generation.

Today's art limits the short-fibered furnish used in TAD processes to greater than about 0.75 mm.

Inventors have now found that, when accompanied by low coarseness and a physical property modifier which can comprise either a permanent wet strength agent or a chemical softening agent, surprisingly low fiber length, i.e. less than about 1.2 mm fibers can be used in the production and use of TAD tissue paper structures and realizing a softness benefit from such fibers which would not hereinbefore be predicted.

No prior art reference teaches a TAD fibrous structure comprising a short fiber furnish comprising a short fiber having a length of from about 0.4 mm to about 1.2 mm and a coarseness of from about 3.0 mg/100 m to about 7.5 mg/100 m, and a physical property ingredient selected from the group consisting of permanent wet strength resins, chemical softeners and mixtures thereof.

SUMMARY OF THE INVENTION

The present invention provides a TAD fibrous structure that comprises a short fiber furnish and a physical property ingredient selected from the group consisting of permanent wet strength resins, chemical softeners and mixtures thereof.

In one aspect of the present invention, a TAD fibrous structure comprising a short fiber furnish comprising a short fiber having a length of from about 0.4 mm to about 1.2 mm and a coarseness of from about 3.0 mg/100 m to about 7.5 mg/100 m, and a physical property ingredient selected from the group consisting of permanent wet strength resins, chemical softeners and mixtures thereof, is provided.

In another aspect of the present invention, a paper product comprising a TAD fibrous structure according to the present invention is provided.

In yet another aspect of the present invention, a sanitary tissue product comprising a TAD fibrous structure wherein the sanitary tissue product is selected from the group consisting of facial tissue products, toilet tissue products, paper towel products and mixtures thereof, is provided.

In yet still another aspect of the present invention, a process for making a through-air dried fibrous structure comprising the steps of:

a. preparing a fibrous furnish comprising a short fiber furnish comprising a short fiber having a length of from about 0.4 mm to about 1.2 mm and a coarseness of from about 3.0 mg/100 m to about 7.5 mg/100 m, by mixing the short fiber with water to form the short fiber furnish;
b. depositing the fibrous furnish on a foraminous forming surface to form an embryonic fibrous web;

c. adding a permanent wet strength resin to the fibrous furnish and/or the embryonic fibrous web; and

d. through-air drying said embryonic fibrous web such that the through-air dried fibrous structure is formed, is provided.

In even yet another aspect of the present invention, a process for making a through-air dried, chemical softener-containing fibrous structure comprising the steps of:

a. preparing a fibrous furnish comprising a short fiber furnish comprising a short fiber having a length of from about 0.4 mm to about 1.2 mm and a coarseness of from about 3.0 mg/100 m to about 7.5 mg/100 m, by mixing the short fiber with water to form the short fiber furnish;

b. depositing the fibrous furnish on a foraminous forming surface to form an embryonic fibrous web;

c. through-air drying said embryonic fibrous web such that a through-air dried fibrous structure is formed; and

d. applying a chemical softener to the fibrous furnish and/or embryonic fibrous web and/or through-air dried fibrous structure such that the through-air dried, chemical softener-containing fibrous structure is formed, is provided.

DETAILED DESCRIPTION OF THE INVENTION

"Fiber" as used herein means a elongate particulate having an apparent length greatly exceeding its apparent width, i.e. a length to diameter ratio of at least about 10. More specifically, as used herein, "fiber" refers to papermaking fibers. The present invention contemplates the use of a variety of papermaking fibers, such as, for example, natural fibers or synthetic fibers, or any other suitable fibers, and any combination thereof. Papermaking fibers useful in the present invention include cellulosic fibers commonly known as wood pulp fibers. Applicable wood pulps include chemical pulps, such as Kraft, sulfite, and sulfate pulps, as well as mechanical pulps including, for example, groundwood, thermomechanical pulp and chemically modified thermomechanical pulp. Chemical pulps, however, may be preferred since they impart a superior tactile sense of softness to tissue sheets made therefrom. Pulps derived from both deciduous trees (hereinafter, also referred to as "hardwood") and coniferous trees (hereinafter, also referred to as "softwood") may be utilized. The hardwood and softwood fibers can be blended, or alternatively, can be deposited in layers to provide a stratified web. U.S. Pat. No. 4,300,981 and U.S. Pat. No. 3,994,771 are incorporated herein by reference for the purpose of disclosing layering of hardwood and softwood fibers. Also applicable to the present invention are fibers derived from recycled paper, which may contain any or all of the above categories as well

as other non-fibrous materials such as fillers and adhesives used to facilitate the original papermaking.

In addition to the various wood pulp fibers, other cellulosic fibers such as cotton linters, rayon, and bagasse can be used in this invention. Synthetic fibers, such as polymeric fibers, can also be used. Elastomeric polymers, polypropylene, polyethylene, polyester, polyolefin, and nylon, can be used. The polymeric fibers can be produced by spunbond processes, meltblown processes, and other suitable methods known in the art.

The embryonic web can be typically prepared from an aqueous dispersion of papermaking fibers, though dispersions in liquids other than water can be used. The fibers are dispersed in the carrier liquid to have a consistency of from about 0.1 to about 0.3 percent. It is believed that the present invention can also be applicable to moist forming operations where the fibers are dispersed in a carrier liquid to have a consistency less than about 50 percent, more preferably less than about 10%.

"Sanitary tissue product" as used herein means a soft, low density (i.e. < about 0.15 g/cm3) web useful as a wiping implement for post-urinary and post-bowel movement cleaning (toilet tissue), for otorhinolaryngolical discharges (facial tissue), and multi-functional absorbent and cleaning uses (absorbent towels).

"Weight average molecular weight" as used herein means the weight average molecular weight as determined using gel permeation chromatography according to the protocol found in Colloids and Surfaces A. Physico Chemical & Engineering Aspects, Vol. 162, 2000, pg. 107-121.

"Wet Burst Strength" as used herein is a measure of the ability of a fibrous structure and/or a paper product incorporating a fibrous structure to absorb energy, when wet and subjected to deformation normal to the plane of the fibrous structure and/or paper product. Wet burst strength may be measured using a Thwing-Albert Burst Tester Cat. No. 177 equipped with a 2000 g load cell commercially available from Thwing-Albert Instrument Company, Philadelphia, PA.

Wet burst strength is measured by taking eight (8) fibrous structures according to the present invention and staking them in four pairs of two (2) samples each. Using scissors, cut the samples so that they are approximately 228 mm in the machine direction and approximately 114 mm in the cross machine direction, each two finished product units thick. First, age the samples for two (2) hours by attaching the sample stack together with a small paper clip and "fan" the other end of the sample stack by a clamp in a 107°C (± 3°C) forced draft oven for 5 minutes (± 10 seconds). After the heating period, remove the sample stack from the oven and cool for a minimum of three (3) minutes before testing. Take one sample strip, holding the sample by the narrow cross machine direction edges, dipping the center of the sample into a pan filled with

about 25 mm of distilled water. Leave the sample in the water four (4) (± 0.5) seconds. Remove and drain for three (3) (± 0.5) seconds holding the sample so the water runs off in the cross machine direction. Proceed with the test immediately after the drain step. Place the wet sample on the lower ring of a sample holding device of the Burst Tester with the outer surface of the sample facing up so that the wet part of the sample completely covers the open surface of the sample holding ring. If wrinkles are present, discard the samples and repeat with a new sample. After the sample is properly in place on the lower sample holding ring, turn the switch that lowers the upper ring on the Burst Tester. The sample to be tested is now securely gripped in the sample holding unit. Start the burst test immediately at this point by pressing the start button on the Burst Tester. A plunger will begin to rise toward the wet surface of the sample. At the point when the sample tears or ruptures, report the maximum reading. The plunger will automatically reverse and return to its original starting position. Repeat this procedure on three (3) more samples for a total of four (4) tests, i.e., four (4) replicates. Report the results as an average of the four (4) replicates, to the nearest g.

"Basis Weight" as used herein is the weight per unit area of a sample reported in lbs/3000 ft^2 or g/m^2. Basis weight is measured by preparing one or more samples of a certain area (m^2) and weighing the sample(s) of a fibrous structure according to the present invention and/or a paper product comprising such fibrous structure on a top loading balance with a minimum resolution of 0.01 g. The balance is protected from air drafts and other disturbances using a draft shield. Weights are recorded when the readings on the balance become constant. The average weight (g) is calculated and the average area of the samples (m^2). The basis weight (g/m^2) is calculated by dividing the average weight (g) by the average area of the samples (m^2).

"Machine Direction" or "MD" as used herein means the direction parallel to the flow of the fibrous structure through the papermaking machine and/or product manufacturing equipment.

"Cross Machine Direction" or "CD" as used herein means the direction perpendicular to the machine direction in the same plane of the fibrous structure and/or paper product comprising the fibrous structure.

"Total Dry Tensile Strength" or "TDT" of a fibrous structure of the present invention and/or a paper product comprising such fibrous structure is measured as follows. One (1) inch by five (5) inch (2.5 cm X 12.7 cm) strips of fibrous structure and/or paper product comprising such fibrous structure are provided. The strip is placed on an electronic tensile tester Model 1122 commercially available from Instron Corp., Canton, Massachusetts in a conditioned room at a temperature of 73°F ± 4°F (about 28°C ± 2.2°C) and a relative humidity of 50% ± 10%. The crosshead speed of the tensile tester is 2.0 inches per minute (about 5.1 cm/minute) and the gauge

length is 4.0 inches (about 10.2 cm). The TDT is the arithmetic total of MD and CD tensile strengths of the strips.

"Caliper" as used herein means the macroscopic thickness of a sample. Caliper of a sample of fibrous structure according to the present invention is determined by cutting a sample of the fibrous structure such that it is larger in size than a load foot loading surface where the load foot loading surface has a circular surface area of about 3.14 in^2. The sample is confined between a horizontal flat surface and the load foot loading surface. The load foot loading surface applies a confining pressure to the sample of 15.5 g/cm^2 (about 0.21 psi). The caliper is the resulting gap between the flat surface and the load foot loading surface. Such measurements can be obtained on a VIR Electronic Thickness Tester Model II available from Thwing-Albert Instrument Company, Philadelphia, PA. The caliper measurement is repeated and recorded at least five (5) times so that an average caliper can be calculated. The result is reported in millimeters.

"Apparent Density" or "Density"as used herein means the basis weight of a sample divided by the caliper with appropriate conversions incorporated therein. Apparent density used herein has the units g/cm^3.

"Softness" of a fibrous structure according to the present invention and/or a paper product comprising such fibrous structure is determined as follows. Ideally, prior to softness testing, the samples to be tested should be conditioned according to Tappi Method #T4020M-88. Here, samples are preconditioned for 24 hours at a relative humidity level of 10 to 35% and within a temperature range of 22°C to 40°C. After this preconditioning step, samples should be conditioned for 24 hours at a relative humidity of 48% to 52% and within a temperature range of 22°C to 24°C. Ideally, the softness panel testing should take place within the confines of a constant temperature and humidity room. If this is not feasible, all samples, including the controls, should experience identical environmental exposure conditions.

Softness testing is performed as a paired comparison in a form similar to that described in "Manual on Sensory Testing Methods", ASTM Special Technical Publication 434, published by the American Society For Testing and Materials 1968 and is incorporated herein by reference. Softness is evaluated by subjective testing using what is referred to as a Paired Difference Test. The method employs a standard external to the test material itself. For tactile perceived softness two samples are presented such that the subject cannot see the samples, and the subject is required to choose one of them on the basis of tactile softness. The result of the test is reported in what is referred to as Panel Score Unit (PSU). With respect to softness testing to obtain the softness data reported herein in PSU, a number of softness panel tests are performed. In each test ten practiced softness judges are asked to rate the relative softness of three sets of paired samples. The pairs of

samples are judged one pair at a time by each judge: one sample of each pair being designated X and the other Y. Briefly, each X sample is graded against its paired Y sample as follows:

1. a grade of plus one is given if X is judged to may be a little softer than Y, and a grade of minus one is given if Y is judged to may be a little softer than X;

2. a grade of plus two is given if X is judged to surely be a little softer than Y, and a grade of minus two is given if Y is judged to surely be a little softer than X;

3. a grade of plus three is given to X if it is judged to be a lot softer than Y, and a grade of minus three is given if Y is judged to be a lot softer than X; and, lastly:

4. a grade of plus four is given to X if it is judged to be a whole lot softer than Y, and a grade of minus 4 is given if Y is judged to be a whole lot softer than X.

The grades are averaged and the resultant value is in units of PSU. The resulting data are considered the results of one panel test. If more than one sample pair is evaluated then all sample pairs are rank ordered according to their grades by paired statistical analysis. Then, the rank is shifted up or down in value as required to give a zero PSU value to which ever sample is chosen to be the zero-base standard. The other samples then have plus or minus values as determined by their relative grades with respect to the zero base standard. The number of panel tests performed and averaged is such that about 0.2 PSU represents a significant difference in subjectively perceived softness.

"Ply" or "Plies" as used herein means an individual fibrous structure optionally to be disposed in a substantially contiguous, face-to-face relationship with other plies, forming a multiple ply fibrous structure. It is also contemplated that a single fibrous structure can effectively form two "plies" or multiple "plies", for example, by being folded on itself.

As used herein, the articles "a" and "an" when used herein, for example, "an anionic surfactant" or "a fiber" is understood to mean one or more of the material that is claimed or described.

All percentages and ratios are calculated by weight unless otherwise indicated. All percentages and ratios are calculated based on the total composition unless otherwise indicated.

Unless otherwise noted, all component or composition levels are in reference to the active level of that component or composition, and are exclusive of impurities, for example, residual solvents or by-products, which may be present in commercially available sources.

TAD Fibrous Structure:

The TAD fibrous structure of the present invention may comprise a fibrous furnish comprising a short fiber furnish comprising a short fiber having a length of from about 0.4 mm to about 1.2 mm and a coarseness of from about 3.0 mg/100 m to about 7.5 mg/100 m.

In addition to the short fiber, the TAD fibrous structure may comprise a wet strength resin, preferably a permanent wet strength resin. Also, in addition to the short fiber, the TAD fibrous structure may comprise a chemical softener. The fibrous furnish used to make the TAD fibrous structure may further comprise a permanent wet strength resin.

The short fibers having a length of from about 0.4 mm to about 1.2 mm and a coarseness of from about 3.0 mg/100 m to about 7.5 mg/100 m may be present in the TAD fibrous structure at a level of at least 10% by weight of the total fibers, and/or at a level of at least 20% up to 100% by weight of the total fibers of the TAD fibrous structure.

In addition to the short fiber, the TAD fibrous structure of the present invention may include optional ingredients, which are described in more detail below.

In addition to the short fiber furnish, the fibrous furnish of the present invention may further comprise a long fiber furnish comprising a long fiber having a length of greater than 1.2 mm. Nonlimiting examples of these long fibers include fibers derived from wood pulp. Other cellulosic fibrous pulp fibers, such as cotton linters, bagasse, etc., can be utilized and are intended to be within the scope of this invention. Synthetic fibers, such as rayon, polyethylene and polypropylene fibers, can also be utilized in combination with natural cellulosic fibers. One exemplary polyethylene fiber that can be utilized is Pulpex(R), available from Hercules, Inc. (Wilmington, Del.).

Applicable wood pulps include chemical pulps, such as Kraft, especially Northern Softwood Kraft ("NSK"), sulfite, and sulfate pulps, as well as mechanical pulps including, for example, groundwood, thermomechanical pulp and chemically modified thermomechanical pulp. Chemical pulps, however, are preferred since they impart a superior tactile sense of softness to tissue sheets made therefrom. Pulps derived from both deciduous trees (hereafter, also referred to as "hardwood") and coniferous trees (hereafter, also referred to as "softwood") can be utilized. Also useful in the present invention are fibers derived from recycled paper, which can contain any or all of the above categories as well as other non-fibrous materials such as fillers and adhesives used to facilitate the original papermaking.

In addition to wood pulps, fibers may be produced/obtained from vegetable sources such as corn (i.e., starch).

The TAD fibrous structures of the present invention are useful in paper, especially sanitary tissue paper products in general, including but not limited to conventionally felt-pressed tissue paper; high bulk pattern densified tissue paper; and high bulk, uncompacted tissue paper. The tissue paper can be of a homogenous or multi-layered construction; and tissue paper products made therefrom can be of a single-ply or multi-ply construction. The tissue paper may have a

basis weight of between about 10 g/m2 to about 65 g/m2, and a density of from about 0.6 g/cc or less.

Conventionally pressed tissue paper and methods for making such paper are well known in the art. Such paper is typically made by depositing a papermaking furnish on a foraminous forming wire, often referred to in the art as a Fourdrinier wire. Once the furnish is deposited on the forming wire, it is referred to as a web. The web is dewatered by pressing the web and drying at elevated temperature. The particular techniques and typical equipment for making webs according to the process just described are well known to those skilled in the art. In a typical process, a low consistency pulp furnish is provided from a pressurized headbox. The headbox has an opening for delivering a thin deposit of pulp furnish onto the Fourdrinier wire to form a wet web. The web is then typically dewatered to a fiber consistency of between about 7% and about 25% (total web weight basis) by vacuum dewatering and further dried by pressing operations wherein the web is subjected to pressure developed by opposing mechanical members, for example, cylindrical rolls. The dewatered web is then further pressed and dried by a steam drum apparatus known in the art as a Yankee dryer. Pressure can be developed at the Yankee dryer by mechanical means such as an opposing cylindrical drum pressing against the web. Multiple Yankee dryer drums can be employed, whereby additional pressing is optionally incurred between the drums. The tissue paper structures that are formed are referred to hereafter as conventional, pressed, tissue paper structures. Such sheets are considered to be compacted since the entire web is subjected to substantial mechanical compressional forces while the fibers are moist and are then dried while in a compressed state.

The TAD fibrous structure may be made with a fibrous furnish that produces a single layer embryonic fibrous web or a fibrous furnish that produces a multi-layer embryonic fibrous web. One or more short fibers may be present in a fibrous furnish with one or more long fibers. Further, one or more short fibers may be present in a furnish layer with one or more long fibers.

The TAD fibrous structures of the present invention and/or paper products comprising such TAD fibrous structures may have a basis weight of from about 12 g/m^2 to about 120 g/m^2 and/or from about 14 g/m^2 to about 80 g/m^2 and/or from about 20 g/m^2 to about 60 g/m^2.

The TAD fibrous structures of the present invention and/or paper products comprising such TAD fibrous structures may have a total dry tensile of greater than about 150 g/in and/or from about 200 g/in to about 1000 g/in and/or from about 250 g/in to about 850 g/in.

The TAD fibrous structures of the present invention and/or paper products comprising such TAD fibrous structures may have a wet burst strength of greater than about 25 g/in and/or from about 30 g/in to about 200 g/in and/or from about 150 g/in to about 500 g/in.

Short Fibers:

The short fibers of the present invention may have a length of from about 0.4 mm to about 1.2 mm and/or from about 0.5 mm to about 0.75 mm and/or from about 0.6 mm to about 0.7 mm and a coarseness of from about 3.0 mg/100 m to about 7.5 mg/100 m and/or from about 5.0 mg/100 m to about 7.5 mg/100 m and/or from about 6.0 mg/100 m to about 7.0 mg/100 m.

The short fibers of the present invention may be derived from a fiber source selected from the group consisting of Acacia, Eucalyptus, Maple, Oak, Aspen, Birch, Cottonwood, Alder, Ash, Cherry, Elm, Hickory, Poplar, Gum, Walnut, Locust, Sycamore, Beech, Catalpa, Sassafras, Gmelina, Albizia, Anthocephalus, Magnolia, Bagasse, Flax, Hemp, Kenaf and mixtures thereof.

In one embodiment, the short fibers are derived from tropical hardwood.

In another embodiment, the short fibers are derived from a fiber source selected from the group consisting of Acacia, Eucalyptus, Gmelina and mixtures thereof.

In another embodiment, the short fibers are derived from a fiber source selected from the group consisting of Acacia, Gmelina and mixtures thereof.

In yet another embodiment, the short fibers are derived from Acacia.

Nonlimiting examples of suitable short fibers having a length of from about 0.4 mm to about 1.2 mm and a coarseness of from about 3.0 mg/100 m to about 7.5 mg/100 m are commercially available from PT Tel of Indonesia.

The short fibers of the present invention may comprise cellulose and/or hemicellulose. Preferably, the fibers comprise cellulose.

The length and coarseness of the short fibers may be determined using a Kajaani FiberLab Fiber Analyzer commercially available from Metso Automation, Kajaani Finland. As used herein, fiber length is defined as the "length weighted average fiber length". The instructions supplied with the unit detail the formula used to arrive at this average. However, the recommended method used to determine fiber lengths and coarseness of fiber specimens essentially the same as detailed by the manufacturer of the Fiber Lab. The recommended consistencies for charging to the Fiber Lab are somewhat lower than recommended by the manufacturer since this gives more reliable operation. Short fiber furnishes, as defined herein, should be diluted to 0.02-0.04% prior to charging to the instrument. Long fiber furnishes, as defined herein, should be diluted to 0.15% - 0.30%. Alternatively, the length and coarseness of the short fibers may be determined by sending the short fibers to an outside contract lab, such as Integrated Paper Services, Appleton, Wisconsin.

Permanent Wet Strength Resins

The TAD fibrous structure of the present invention may comprise a permanent wet strength resin. The permanent wet strength resin may be present in the fibrous furnish, particularly, the short fiber furnish used to form the TAD fibrous structure and/or can be

deposited onto the embryonic fibrous web prior to through-air drying of the embryonic fibrous web.

The permanent wet strength resins act to control linting and also to offset the loss in tensile strength, if any, resulting from the any chemical softeners added to the fibrous structure. Further, the permanent wet strength resins give the fibrous structure or paper product it is incorporated into a property such that when it is placed in an aqueous medium it retains a substantial portion of its initial wet strength over time

Nonlimiting examples of permanent wet strength resins include: polyamide-epichlorohydrin resins, polyacrylamide resins, styrenebutadiene resins; insolubilized polyvinyl alcohol resins; urea-formaldehyde resins; polyethyleneimine resins; chitosan resins and mixtures thereof. Preferably, the permanent wet strength resins are selected from the group consisting of polyamide-epichlorohydrin resins, polyacrylamide resins and mixtures thereof.

Polyamide-epichlorohydrin resins are cationic wet strength resins which have been found to be of particular utility. Suitable types of such resins are described in U.S. Pat. Nos. 3,700,623, issued on Oct. 24, 1972, and 3,772,076, issued on Nov. 13, 1973, both issued to Keim and both being hereby incorporated by reference. One commercial source of a useful polyamide-epichlorohydrin resins is Hercules, Inc. of Wilmington, Del., which markets such resin under the trade-mark KYMENE ® 557H.

Polyacrylamide resins have also been found to be of utility as wet strength resins. These resins are described in U.S. Pat. Nos. 3,556,932, issued on Jan. 19, 1971, to Coscia, et al. and 3,556,933, issued on Jan. 19, 1971, to Williams et al., both patents being incorporated herein by reference. One commercial source of polyacrylamide resins is CYTEC Co. of Stanford, Conn., which markets one such resin under the trade-mark PAREZ ® 631 NC. Still other water-soluble cationic resins finding utility in this invention are urea formaldehyde and melamine formaldehyde resins.

Chemical Softeners:

The TAD fibrous structure of the present invention may comprise a chemical softener.

As used herein, the term "chemical softener" and/or "chemical softening agent" refers to any chemical ingredient which improves the tactile sensation perceived by the user whom holds a particular paper product and rubs it across her skin. Although somewhat desirable for towel products, softness is a particularly important property for facial and toilet tissues. Such tactile perceivable softness can be characterized by, but is not limited to, friction, flexibility, and smoothness, as well as subjective descriptors, such as a feeling like lubricious, velvet, silk or flannel.

Chemical softening agent is any chemical ingredient which imparts a lubricious feel to tissue. This includes, for exemplary purposes only, basic waxes such as paraffin and beeswax and oils such as mineral oil and silicone oils and silicone gels as well as petrolatum and more complex lubricants and emollients such as quaternary ammonium compounds with long (C10 – C22) hydrocarbyl chains, functional silicones, and long (C10 – C22) hydrocarbyl chain-bearing compounds possessing functional groups such as amines, acids, alcohols and esters.

The field of work in the prior art pertaining to chemical softeners has taken two paths. The first path is characterized by the addition of softeners to the tissue paper web during its formation either by adding an attractive ingredient to the vats of pulp which will ultimately be formed into a tissue paper web, to the pulp slurry as it approaches a paper making machine, or to the wet web as it resides on a Fourdrinier cloth or dryer cloth on a paper making machine.

The second path is categorized by the addition of chemical softeners to tissue paper web after the web is partially or completely dried. Applicable processes can be incorporated into the paper making operation as, for example, by spraying onto the embryonic web and/or dried fibrous structure before it is wound into a roll of paper, extruding, especially via slot extrusion, onto the embryonic web and/or dried fibrous structure, and/or by gravure printing onto the embryonic web and/or dried fibrous structure.

Exemplary art related to the former path categorized by adding chemical softeners to the tissue paper prior to its assembly into a web includes U.S. Pat. 5,264,082 issued to Phan and Trokhan on Nov. 23, 1993, incorporated herein by reference. Such methods have found broad use in the industry especially when it is desired to reduce the strength which would otherwise be present in the paper and when the papermaking process, particularly the creping operation, is robust enough to tolerate incorporation of the bond inhibiting agents.

Further exemplary art related to the addition of chemical softeners to the tissue paper web during its formation includes U.S. Pat. No. 5,059,282 issued to Ampulski, et. al. on Oct. 22, 1991 incorporated herein by reference. The Ampulski patent discloses a process for adding a polysiloxane compound to a wet tissue web (preferably at a fiber consistency between about 20% and about 35%). Such a method represents an advance in some respects over the addition of chemicals into the slurry vats supplying the papermaking machine. For example, such means target the application to one of the web surfaces as opposed to distributing the additive onto all of the fibers of the furnish.

Considerable art has been devised to apply chemical softeners to already-dried paper webs either at the so-called dry end of the papermaking machine or in a separate converting operation subsequent to the papermaking step. Exemplary art from this field includes U.S. Pat. No. 5,215,626 issued to Ampulski, et. al. on Jun. 1, 1993; U.S. Pat. No. 5,246,545 issued to

Ampulski, et. al. on Sep. 21, 1993; and U.S. Pat. No. 5,525,345 issued to Warner, et. al. on Jun. 11, 1996, all incorporated herein by reference. The U.S. Pat. No. 5,215,626 discloses a method for preparing soft tissue paper by applying a polysiloxane to a dry web. The U.S. Pat. No.5,246,545 Patent discloses a similar method utilizing a heated transfer surface. Finally, the Warner Patent discloses methods of application including roll coating and extrusion for applying particular compositions to the surface of a dry tissue web.

Particularly preferred chemical softening ingredients are further detailed as follows:

i. Quaternary Ammonium Softeners

Preferably, quaternary ammonium compounds suitable to serve as chemical softening agents of the present invention have the formula:

$$(R^1)_{4-m}—N+—[R^2]_m \quad X^-$$

wherein:

m is 1 to 3; each R^1 is independently a C_1 -C_6 alkyl group, hydroxyalkyl group, hydrocarbyl or substituted hydrocarbyl group, alkoxylated group, benzyl group, or mixtures thereof; each R^2 is independently a C_{14} -C_{22} alkyl group, hydroxyalkyl group, hydrocarbyl or substituted hydrocarbyl group, alkoxylated group, benzyl group, or mixtures thereof; and X^- is any softener-compatible anion are suitable for use in the present invention.

Preferably, each R^1 is methyl and X^- is chloride or methyl sulfate. Preferably, each R^2 is independently C_{16} -C_{18} alkyl or alkenyl, most preferably each R^2 is independently straight-chain C_{18} alkyl or alkenyl.

Particularly preferred variants of these softening agents are what are considered to be mono or diester variations of these quaternary ammonium compounds having the formula:

$$(R^1)_{4-m}—N+—[(CH_2)_n—Y—R^3]_m \quad X^-$$

wherein:

Y is —O— (O)C—, or —C(O) —O—, or —NH—C(O) —, or —C(O) —NH—; m is 1 to 3; n is 0to 4; each R^1 is independently a C_1 -C_6 alkyl group, hydroxyalkyl group, hydrocarbyl or substituted hydrocarbyl group, alkoxylated group, benzyl group, or mixtures thereof; each R^3 is independently a C_{13} -C_{21} alkyl group, hydroxyalkyl group, hydrocarbyl or substituted hydrocarbyl group, alkoxylated group, benzyl group, or mixtures thereof, and X^- is any softener-compatible anion.

Preferably, Y is —O— (O)C—, or —C(O) —O—; m=2; and n=2. Each R^1 is independently preferably a C_1 -C_3, alkyl group, with methyl being most preferred. Preferably, each R^3 is independently C_{13} -C_{17} alkyl and/or alkenyl, more preferably R^3 is independently straight chain C_{15} -C_{17} alkyl and/or alkenyl, C_{15} -C_{17} alkyl, most preferably each R^3 is independently straight-chain C_{17} alkyl.

As mentioned above, X^- can be any softener-compatible anion, for example, acetate, chloride, bromide, methyl sulfate, formate, sulfate, nitrate and the like can also be used in the present invention. Preferably X^- is chloride or methyl sulfate.

One particularly preferred material is so-called DEEDMAMS (diethyl ester dimethyl ammonium methyl sulfate), further defined herein wherein the hydrocarbyl chains are derived from tallow fatty acids optionally partially hardened to an iodine value from about 10 to about 60.

ii. Emollient Lotion Composition

Suitable chemical softening agents as defined herein may include emollient lotion compositions. As used herein, an "emollient lotion composition" is a chemical softening agent that softens, soothes, supples, coats, lubricates, or moisturizes the skin. An emollient typically accomplishes several of these objectives such as soothing, moisturizing, and lubricating the skin.

Emollients useful in the present invention can be petroleum-based, fatty acid ester type, alkyl ethoxylate type, or mixtures of these emollients. Suitable petroleum-based emollients include those hydrocarbons, or mixtures of hydrocarbons, having chain lengths of from 16 to 32 carbon atoms. Petroleum based hydrocarbons having these chain lengths include mineral oil (also known as "liquid petrolatum") and petrolatum (also known as "mineral wax," "petroleum jelly" and "mineral jelly"). Mineral oil usually refers to less viscous mixtures of hydrocarbons having from 16 to 20 carbon atoms. Petrolatum usually refers to more viscous mixtures of hydrocarbons having from 16 to 32 carbon atoms. Petrolatum is a particularly preferred emollient for use in fibrous structures that are incorporated into toilet tissue products. and a suitable material is available from Witco, Corp., Greenwich, Conn. as White Protopet® IS. Mineral oil is also a preferred emollient for use in fibrous structures that are incorporated into facial tissue products. Such mineral oil is commercially available also from Witco Corp.

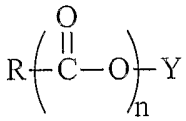
Suitable fatty acid ester type emollients include those derived from C_{12} -C_{28} fatty acids, preferably C_{16} -C_{22} saturated fatty acids, and short chain (C_1 -C_8, preferably C_1 -C_3) monohydric alcohols. Representative examples of such esters include methyl palmitate, methyl stearate, isopropyl laurate, isopropyl myristate, isopropyl palmitate, and ethylhexyl palmitate. Suitable fatty acid ester emollients can also be derived from esters of longer chain fatty alcohols (C_{12} -C_{28}, preferably C_{12} -C_{16}) and shorter chain fatty acids e.g., lactic acid, such as lauryl lactate and cetyl lactate.

Suitable alkyl ethoxylate type emollients include C_{12} -C_{18} fatty alcohol ethoxylates having an average of from 3 to 30 oxyethylene units, preferably from about 4 to about 23. Representative examples of such alkyl ethoxylates include laureth-3 (a lauryl ethoxylate having an average of 3 oxyethylene units), laureth-23 (a lauryl ethoxylate having an average of 23 oxyethylene units), ceteth-10 (acetyl ethoxylate having an average of 10 oxyethylene units) and steareth-10 (a stearyl

ethoxylate having an average of 10 oxyethylene units). These alkyl ethoxylate emollients are typically used in combination with the petroleum-based emollients, such as petrolatum, at a weight ratio of alkyl ethoxylate emollient to petroleum-based emollient of from about 1:1 to about 1:3, preferably from about 1:1.5 to about 1:2.5.

Emollient lotion compositions may optionally include an "immobilizing agents", so-called because it is believed to act to prevent migration of the emollient so that it can remain primarily on the surface of the paper structure to which it is applied so that it may deliver maximum softening benefit as well as be available for transferability to the users skin. Suitable immobilizing agents for the present invention can comprise polyhydroxy fatty acid esters, polyhydroxy fatty acid amides, and mixtures thereof. To be useful as immobilizing agents, the polyhydroxy moiety of the ester or amide has to have at least two free hydroxy groups. It is believed that these free hydroxy groups are the ones that co-crosslink through hydrogen bonds with the cellulosic fibers of the tissue paper web to which the lotion composition is applied and homo-crosslink, also through hydrogen bonds, the hydroxy groups of the ester or amide, thus entrapping and immobilizing the other components in the lotion matrix. Preferred esters and amides will have three or more free hydroxy groups on the polyhydroxy moiety and are typically nonionic in character. Because of the skin sensitivity of those using paper products to which the lotion composition is applied, these esters and amides should also be relatively mild and non-irritating to the skin.

Suitable polyhydroxy fatty acid esters for use in the present invention will have the formula:



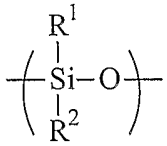
wherein R is a C_5 -C_{31} hydrocarbyl group, preferably straight chain C_7 -C_{19} alkyl or alkenyl, more preferably straight chain C_9 -C_{17} alkyl or alkenyl, most preferably straight chain C_{11} -C_{17} alkyl or alkenyl, or mixture thereof; Y is a polyhydroxyhydrocarbyl moiety having a hydrocarbyl chain with at least 2 free hydroxyls directly connected to the chain; and n is at least 1. Suitable Y groups can be derived from polyols such as glycerol, pentaerythritol; sugars such as raffinose, maltodextrose, galactose, sucrose, glucose, xylose, fructose, maltose, lactose, mannose and erythrose; sugar alcohols such as erythritol, xylitol, malitol, mannitol and sorbitol; and anhydrides of sugar alcohols such as sorbitan.

One class of suitable polyhydroxy fatty acid esters for use in the present invention comprises certain sorbitan esters, preferably the sorbitan esters of C_{16} -C_{22} saturated fatty acids. Because of the manner in which they are typically manufactured, these sorbitan esters usually comprise mixtures of mono-, di-, tri-, etc. esters. Representative examples of suitable sorbitan

esters include sorbitan palmitates (e.g., SPAN 40), sorbitan stearates (e.g., SPAN 60), and sorbitan behenates, that comprise one or more of the mono-, di- and tri-ester versions of these sorbitan esters, e.g., sorbitan mono-, di- and tri-palmitate, sorbitan mono-, di- and tri-stearate, sorbitan mono-, di and ri-behenate, as well as mixed tallow fatty acid sorbitan mono-, di- and tri-esters. Mixtures of different sorbitan esters can also be used, such as sorbitan palmitates with sorbitan stearates. Particularly preferred sorbitan esters are the sorbitan stearates, typically as a mixture of mono-, di- and tri-esters (plus some tetraester) such as SPAN 60, and sorbitan stearates sold under the trade name GLYCOMUL-S by Lonza, Inc. Although these sorbitan esters typically contain mixtures of mono-, di- and tri-esters, plus some tetraester, the mono-and di-esters are usually the predominant species in these mixtures.

iii. Polysiloxanes and/or other Silicone Materials

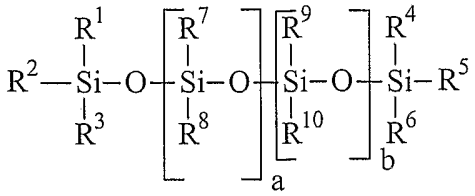
Other suitable chemical softening agents suitable for the invention include silicone materials, such as polysiloxane compounds, cationic silicones, quaternary silicone compounds and/or aminosilicones. In general, suitable polysiloxane materials for use in the present invention include those having monomeric siloxane units of the following structure:



wherein, R^1 and R2, for each independent siloxane monomeric unit can each independently be hydrogen or any alkyl, aryl, alkenyl, alkaryl, arakyl, cycloalkyl, halogenated hydrocarbon, or other radical. Any of such radicals can be substituted or unsubstituted. R^1 and R^2 radicals of any particular monomeric unit may differ from the corresponding functionalities of the next adjoining monomeric unit. Additionally, the polysiloxane can be either a straight chain, a branched chain or have a cyclic structure. The radicals R^1 and R^2 can additionally independently be other silaceous functionalities such as, but not limited to siloxanes, polysiloxanes, silanes, and polysilanes. The radicals R^1 and R^2 may contain any of a variety of organic functionalities including, for example, alcohol, carboxylic acid, phenyl, and amine functionalities.

Exemplary alkyl radicals are methyl, ethyl, propyl, butyl, pentyl, hexyl, octyl, decyl, octadecyl, and the like. Exemplary alkenyl radicals are vinyl, allyl, and the like. Exemplary aryl radicals are phenyl, diphenyl, naphthyl, and the like. Exemplary alkaryl radicals are toyl, xylyl, ethylphenyl, and the like. Exemplary aralkyl radicals are benzyl, alpha-phenylethyl, beta-phenylethyl, alpha-phenylbutyl, and the like. Exemplary cycloalkyl radicals are cyclobutyl, cyclopentyl, cyclohexyl, and the like. Exemplary halogenated hydrocarbon radicals are chloromethyl, bromoethyl, tetrafluorethyl, fluorethyl, trifluorethyl, trifluorotloyl, hexafluoroxylyl, and the like.

Preferred polysiloxanes include straight chain organopolysiloxane materials of the following general formula:



wherein each R^1 -R^9 radical can independently be any C_1 -C_{10} unsubstituted alkyl or aryl radical, and R^{10} of any substituted C_1 -C_{10} alkyl or aryl radical. Preferably each R^1 -R^9 radical is independently any C_1 -C_4 unsubstituted alkyl group. those skilled in the art will recognize that technically there is no difference whether, for example, R^9 or R^{10} is the substituted radical. Preferably the mole ratio of b to (a+b) is between 0 and about 20%, more preferably between 0 and about 10%, and most preferably between about 1% and about 5%.

In one particularly preferred embodiment, R^1 -R^9 are methyl groups and R^{10} is a substituted or unsubstituted alkyl, aryl, or alkenyl group. Such material shall be generally described herein as polydimethylsiloxane which has a particular functionality as may be appropriate in that particular case. Exemplary polydimethylsiloxane include, for example, polydimethylsiloxane having an alkyl hydrocarbon R^{10} radical and polydimethylsiloxane having one or more amino, carboxyl, hydroxyl, ether, polyether, aldehyde, ketone, amide, ester, thiol, and/or other functionalities including alkyl and alkenyl analogs of such functionalities. For example, an amino functional alkyl group as R^{10} could be an amino functional or an aminoalkyl-functional polydimethylsiloxane. The exemplary listing of these polydimethylsiloxanes is not meant to thereby exclude others not specifically listed.

Viscosity of polysiloxanes useful for this invention may vary as widely as the viscosity of polysiloxanes in general vary, so long as the polysiloxane can be rendered into a form which can be applied to the tissue paper product herein. This includes, but is not limited to, viscosity as low as about 25 centistokes to about 20,000,000 centistokes or even higher.

While not wishing to be bound by theory, it is believed that the tactile benefit efficacy is related to average molecular weight and that viscosity is also related to average molecular weight. Accordingly, due to the difficulty of measuring molecular weight directly, viscosity is used herein as the apparent operative parameter with respect to imparting softness to tissue paper.

References disclosing polysiloxanes include U.S. Pat. No. 2,826,551, issued to Geen on Mar. 11, 1958; U.S. Pat. No. 3,964,500, issued to Drakoff on Jun. 22, 1976; U.S. Pat. No. 4,364,837, issued to Pader on Dec. 21, 1982; U.S. Pat. No. 5,059,282, issued to Ampulski; U.S. Pat. No. 5,529,665 issued to Kaun on Jun 25, 1996; U.S. Pat. No. 5,552,020 issued to Smithe et al. on Sep. 3, 1996; and British Patent 849,433, published on Sep. 28, 1960 in the name of

Wooston. All of these patents are incorporated herein by reference. Also incorporated herein by reference is Silicone Compounds, pp. 181-217, distributed by Petrach Systems, Inc., which contains an extensive listing and description of polysiloxanes in general.

In one embodiment, the chemical softeners may be mixed with the fibers, especially the short fibers to form the fibrous furnish, especially the short fiber furnish.

In another embodiment, the chemical softeners may be applied to the embryonic fibrous web and/or the TAD fibrous structure. Application of the chemical softener to the embryonic fibrous web and/or TAD fibrous structure may be by any suitable process known to those of ordinary skill in the art. Nonlimiting examples of such application processes include spraying the chemical softener onto the embryonic fibrous web and/or TAD fibrous structure and/or extruding the chemical softener onto the embryonic fibrous web and/or TAD fibrous structure. Other application processes include brushing the chemical softener onto the embryonic fibrous web and/or TAD fibrous structure and/or dipping the embryonic fibrous web and/or TAD fibrous structure in the chemical softener.

Optional Ingredients:

The TAD fibrous structure of the present invention may comprise an optional ingredient selected from the group consisting of temporary wet strength resins, dry strength resins, wetting agents, lint resisting agents, absorbency-enhancing agents, immobilizing agents, especially in combination with emollient lotion compositions, antiviral agents including organic acids, antibacterial agents, polyol polyesters, antimigration agents, polyhydroxy plasticizers and mixtures thereof. Such optional ingredients may be added to the fiber furnish, the embryonic fibrous web and/or the TAD fibrous structure.

Such optional ingredients may be present in the TAD fibrous structure at any level based on the dry weight of the TAD fibrous structure.

The optional ingredients may be present in the TAD fibrous structure at a level of from about 0.001 to about 50% and/or from about 0.001 to about 20% and/or from about 0.01 to about 5% and/or from about 0.03 to about 3% and/or from about 0.1 to about 1.0% by weight, on a dry TAD fibrous structure basis.

i. Temporary Wet Strength Additives

One method of delivering fugitive wet strength is to provide for the formation of acid-catalysed hemiacetal formation through the introduction of ketone or, more specifically aldehyde functional groups on the papermaking fibers or in a binder additive for the papermaking fibers. One binder material that have been found particularly useful for imparting this form of fugitive wet strength is Parez 750 offered by Cytec of Stamford, CT.

Other additives can also be used to augment this wet strength mechanism. This technique for delivering fugitive wet strength is well known in the art. Exemplary art, incorporated herein by reference for the purpose of showing methods of delivering the fugitive wet strength to the web, includes the following US Patent No. 5,690,790; 5,656,746; 5,723,022; 4,981,557; 5,008,344; 5,085,736; 5,760,212; 4,605,702; 6,228,126; 4,079,043; 4,035,229; 4,079,044; and 6,127,593.

While the hemiacetal formation mechanism is one suitable technique for generating temporary wet strength, there are other methods, such as providing the sheet with a binder mechanism which is more active in the dry or slightly wet condition than in the condition of high dilution as would be experienced in the toilet bowl or in the subsequent sewer and septic system. Such methods have been primarily directed at web products which are to be delivered in a slightly moist or wet condition, then will be disposed under situation of high dilution. The following references are incorporated herein by reference for the purpose of showing exemplary systems to accomplish this, and those skilled in the art will readily recognize that they can be applied to the webs of the present invention which will be supplied generally at lower moisture content than those described therewithin: US Patent Nos. 4,537,807; 4,419,403; 4,309,469; and 4,362,781.

ii. Dry Strength Additives

Nonlimiting examples of dry strength resins include polyacrylamides (such as combinations of CYPRO 514 and ACCOSTRENGTH 711 produced by Cytec of Stamford CT; starch, for example corn starch and/or potato starch (such as REDIBOND 5320 and 2005) available from National Starch and Chemical Company, Bridgewater, N.J.; polyvinyl alcohol (such as AIRVOL ® 540 produced by Air Products Inc of Allentown, Pa.); guar or locust bean gums; and/or carboxymethyl cellulose (such as CMC from Hercules, Inc. of Wilmington, Del.). Dry strength additives are used in more or less amounts to control tensile strength and lint levels.

iii. Wetting Agents

Nonlimiting examples of wetting agents suitable for use in the present invention include polyhydroxy compounds, such as glyercol and polyglycols, and nonionic surfactants, such as addition products of ethylene oxide and, optionally, propylene oxide, with fatty alcohols, fatty acids and fatty amines.

The above listing of optional ingredients is intended to be merely exemplary in nature, and is not meant to limit the scope of the invention.

Processes of the Present Invention:

The TAD fibrous structure of the present invention may be made by any suitable TAD papermaking process.

A nonlimiting example of a suitable TAD papermaking process for making the TAD fibrous structure of the present invention is described as follows.

In one embodiment, a short fiber furnish is prepared by mixing a short fiber with water. One or more additional ingredients such as a physical property ingredient and/or optional ingredients may be added to the short fiber furnish. The short fiber furnish may then be put into a headbox of a papermaking machine. The short fiber furnish may then be deposited on a foraminous surface to form a single layer embryonic fibrous web. Physical property ingredients and/or optional ingredients may be added to the embryonic fibrous web by spraying and/or extruding and/or by any other suitable process known to those of ordinary skill in the art. The embryonic web may then be transferred to a through-air drying belt such that the embryonic fibrous web is dried via through-air drying. From the through-air drying belt, the TAD fibrous structure may be transferred to a Yankee dryer. From the Yankee dryer, the TAD fibrous structure may be wound into a roll.

From the through-air drying belt, or after transfer to a Yankee dryer, if such a dryer is employed, the TAD fibrous structure may be wound into a roll. Physical property ingredients and/or optional ingredients may be applied to the TAD fibrous structure while it is semi-dry or after dried completely. The TAD fibrous structure may be converted into various paper products, particularly sanitary tissue products, both in single-ply forms and/or in multi-ply forms.

In another embodiment, a TAD fibrous structure is prepared from a short fiber furnish and a long fiber furnish. The long fiber furnish may be made by mixing a long fiber with water. The long fiber furnish may include one or more additional ingredients such as a physical property ingredient and/or optional ingredients. These one or more additional ingredients may be present in the long and/or short fiber furnish. The fibrous furnish may be placed in a layered headbox of a papermaking machine. The fibrous furnishes may then be deposited on a foraminous surface to form a multi-layered embryonic fibrous web wherein the long fiber furnish is directed into one or more layers and the short fiber furnish is directed into one or more layers.

Preferred layering methodology for structures which will be assembled into two-ply products include two-layered structures wherein the short fiber furnish is applied into a surface layer, i.e. the layer which will be in contact with a user of the product. In this case , the long fiber furnish layer will be directed toward the inside of the two-ply assembly.

Preferred layering methodology for structures which will be converted into single-ply products include three-layered structures wherein the short fiber furnish is applied into the surface layers surrounding a central long fibered layer.

Physical property ingredients and/or optional ingredients may be added to the embryonic fibrous web by spraying and/or extruding and/or by any other suitable process known to those of

ordinary skill in the art. The embryonic web may then be transferred to a through-air drying belt such that the embryonic fibrous web is dried via through-air drying.

Physical property ingredients and/or optional ingredients may be added to the semi-dry or dry fibrous web by spraying and/or extruding and/or by any other suitable process known to those of ordinary skill in the art.

From the through-air drying belt, or after transfer to a Yankee dryer, if such a dryer is employed, the TAD fibrous structure may be wound into a roll. Physical property ingredients and/or optional ingredients may be applied to the TAD fibrous structure while it is semi-dry or after dried completely. The TAD fibrous structure may be converted into various paper products, particularly sanitary tissue products, both in single-ply forms and/or in multi-ply forms. The paper products may be designed such that the surface of the paper product that is intended to contact a human's skin comprises a short fiber furnish and/or a short fiber.

Example 1

This Example illustrates a process incorporating a preferred embodiment of the present invention using the pilot scale Fourdrinier to make a facial tissue product.

An aqueous slurry of Northern Softwood Kraft (NSK) of about 3% consistency is made up using a conventional pulper and is passed through a stock pipe toward the headbox of the Fourdrinier.

In order to impart a permanent wet strength to the finished product, a 1% dispersion of Hercules' Kymene 557 LX is prepared and is added to the NSK stock pipe at a rate sufficient to deliver 0.7% Kymene 557 LX based on the dry weight of the ultimate paper. The absorption of the permanent wet strength resin is enhanced by passing the treated slurry through an in-line mixer. Carboxymethyl cellulose (CMC) is added next to the NSK stock pipe after the in-line mixer. CMC is first dissolved in water and diluted to a solution strength of 1% by weight. Hercules CMC-7MT® is used to make-up the CMC solution. The aqueous solution of CMC is added to the aqueous slurry of NSK fibers at a rate of 0.15% CMC by weight based on the dry weight of the ultimate paper. The aqueous slurry of NSK fibers passes through a centrifugal stock pump to aid in distributing the CMC. The chemical softening composition is added next. The chemical softening composition is DiTallow DiMethyl Ammonium Methyl Sulfate (DTDMAMS). Pre-heated DTDMAMS (170° F.) is first slurried in water conditioned by pre-heating to 170° F. The water is agitated during addition of the DTDMAMS to aid in its dispersion. The concentration of the resultant DTDMAMS dispersion is 1% by weight, and it is added to the NSK stock pipe at a rate of 0.2% by weight DTDMAMS based on the dry weight of the ultimate paper. The NSK slurry is diluted with white water to about 0.2% consistency at the fan pump.

An aqueous slurry of acacia fibers (from PT Tel - Indonesia) of about 3% by weight is made up using a conventional repulper. The Acacia furnish has a weighted average fiber length of 0.66mm and a coarseness of 7.1 mg/100m. The Acacia slurry passes to the second fan pump where it is diluted with white water to a consistency of about 0.2%.

The slurries of NSK and acacia are directed into a multi-channeled headbox suitably equipped with layering leaves to maintain the streams as separate layers until discharged onto a traveling Fourdrinier wire. A three-chambered headbox is used. The acacia slurry containing 64% of the dry weight of the ultimate paper is directed to the chambers leading to the outer layer, while the NSK slurry comprising 36% of the dry weight of the ultimate paper is directed to the chamber leading to the layer in contact with the wire and to the central layer. The NSK and acacia slurries are combined at the discharge of the headbox into a composite slurry.

The composite slurry is discharged onto the traveling Fourdrinier wire and is dewatered assisted by a deflector and vacuum boxes. The embryonic wet web is transferred from the Fourdrinier wire, at a fiber consistency of about 17% by weight at the point of transfer, to a patterned drying fabric. The drying fabric is designed to yield a pattern-densified tissue with discontinuous low-density deflected areas arranged within a continuous network of high density (knuckle) areas. This drying fabric is formed by casting an impervious resin surface onto a fiber mesh supporting fabric. The supporting fabric is a 48 x 52 filament, dual layer mesh. The thickness of the resin cast is about 12 mil above the supporting fabric. The knuckle area is about 30% and the open cells remain at a frequency of about 68 per square inch.

Further de-watering is accomplished by vacuum assisted drainage until the web has a fiber consistency of about 22% by weight. While remaining in contact with the patterned forming fabric, the patterned web is pre-dried by air blow-through pre-dryer to a fiber consistency of about 58% by weight.

The semi-dry web is then adhered to the surface of a Yankee dryer with a sprayed creping adhesive comprising a 0.250% aqueous solution of polyvinyl alcohol. The creping adhesive is delivered to the Yankee surface at a rate of 0.1% adhesive solids based on the dry weight of the web.

The fiber consistency is increased to about 98% before the web is dry creped from the Yankee with a doctor blade. The doctor blade has a bevel angle of about 20 degrees and is positioned with respect to the Yankee dryer to provide an impact angle of about 76 degrees. The Yankee dryer is operated at a temperature of about 350oF (177oC) and a speed of about 800 fpm (feet per minute) (about 244 meters per minute). The paper is wound in a roll using a surface driven reel drum having a surface speed of about 680 fpm (about 207 meters per minute), thus resulting in a crepe of about 15%.

After the doctor blade, the web is calendered across all its width with a steel to rubber calendar roll operating at a loading of 400 psi. Resulting tissue has a basis weight of about 20 g/m2; a 1-ply total dry tensile between 210 and 240 g/in, a 1-ply wet burst between 35 and 65 g/in and a 2-ply caliper of about 0.020 inches. Resulting tissue is then plied together with a like sheet to form a two-ply, creped, pattern densified tissue so that the acacia fibers face the outside. The resulting two-ply tissue has a) a total basis weight of about 39 g/m2; b) a 2-ply total dry tensile between 350 and 420 g/in; c) a 2-ply wet burst between 90 and 130 g/in; and d) a 4-ply caliper of about 0.028 inches.

Example 2

The same 2-ply, creped, pattern densified tissue, with the acacia fibers facing outside presented in Example #1, adding CM849 - an amino functional dimethyl polysiloxane sold by General Electric Silicones of Waterford, N.Y. – via slot extrusion onto both sides in contact with a human's skin, at an add-on amount of approximately 0.3-0.5 percent of silicone per ply based on the total weight of fibers. A comparative product is made in the same manner as this example except that a Eucalyptus bleached kraft fibrous pulp is substituted for the Acacia bleached kraft fibrous pulp. The Eucalyptus pulp furnish has a fiber length of 0.73mm and a coarseness of 8.0 mg/100m. The resultant tissue paper using the comparative furnish is judged less soft by a panel of expert judges.

Example 3

This Example illustrates another process incorporating a preferred embodiment of the present invention using the pilot scale Fourdrinier to make a facial tissue product. An aqueous slurry of Northern Softwood Kraft (NSK) of about 3% consistency is made up using a conventional pulper and is passed through a stock pipe toward the headbox of the Fourdrinier.

In order to impart a permanent wet strength to the finished product, a 1% dispersion of Hercules' Kymene 557 LX is prepared and is added to the NSK stock pipe at a rate sufficient to deliver 0.9% Kymene 557 LX based on the dry weight of the ultimate paper. The absorption of the permanent wet strength resin is enhanced by passing the treated slurry through an in-line mixer. Carboxymethyl cellulose (CMC) is added next to the NSK stock pipe after the in-line mixer. CMC is first dissolved in water and diluted to a solution strength of 1% by weight. Hercules CMC-7MT® is used to make-up the CMC solution. The aqueous solution of CMC is added to the aqueous slurry of NSK fibers at a rate of 0.15% CMC by weight based on the dry weight of the ultimate paper. The aqueous slurry of NSK fibers passes through a centrifugal stock pump to aid in distributing the CMC. The bonding inhibitor composition is added next. The bonding inhibitor composition is DiTallow DiMethyl Ammonium Methyl Sulfate (DTDMAMS). Pre-heated DTDMAMS (170° F.) is first slurried in water conditioned by pre-heating to 170° F.

The water is agitated during addition of the DTDMAMS to aid in its dispersion. The concentration of the resultant DTDMAMS dispersion is 1% by weight, and it is added to the NSK stock pipe at a rate of 0.125% by weight DTDMAMS based on the dry weight of the ultimate paper.

An aqueous slurry of acacia fibers (from PT Tel – Indonesia) of about 1.5% by weight is made up using a conventional repulper and is passed through a stock pipe toward the headbox of the Fourdrinier. The Acacia furnish has a weighted average fiber length of 0.66 mm and a coarseness of 7.1 mg/100m. This Acacia furnish joins the NSK slurry at the fan pump where both are diluted with white water to about 0.2% consistency.

An aqueous slurry of acacia fibers (from PT Tel - Indonesia) of about 3% by weight is made up using a conventional repulper. The Acacia slurry passes to the second fan pump where it is diluted with white water to a consistency of about 0.2%.

The slurries of NSK/acacia and acacia are directed into a multi-channeled headbox suitably equipped with layering leaves to maintain the streams as separate layers until discharged onto a traveling Fourdrinier wire. A three-chambered headbox is used. The acacia slurry containing 53% of the dry weight of the ultimate paper is directed to the chambers leading to the outer layer, while the NSK/acacia slurry comprising 47% (30% NSK and 17% acacia) of the dry weight of the ultimate paper is directed to the chamber leading to the layer in contact with the wire and to the chamber leading to the layer between the outer layer and the layer in contact with the wire. The NSK/acacia and acacia slurries are combined at the discharge of the headbox into a composite slurry.

The composite slurry is discharged onto the traveling Fourdrinier wire and is dewatered assisted by a deflector and vacuum boxes. The embryonic wet web is transferred from the Fourdrinier wire, at a fiber consistency of about 18% by weight at the point of transfer, to a patterned drying fabric. The drying fabric is designed to yield a pattern-densified tissue with discontinuous low-density deflected areas arranged within a continuous network of high density (knuckle) areas. This drying fabric is formed by casting an impervious resin surface onto a fiber mesh supporting fabric. The supporting fabric is a 48 x 52 filament, dual layer mesh. The thickness of the resin cast is about 9 mil above the supporting fabric. The knuckle area is about 40% and the open cells remain at a frequency of about 68 per square inch.

Further de-watering is accomplished by vacuum assisted drainage until the web has a fiber consistency of about 26%. While remaining in contact with the patterned forming fabric, the patterned web is pre-dried by air blown through to a fiber consistency of about 59% by weight.

The semi-dry web is then adhered to the surface of a Yankee dryer with a sprayed creping adhesive comprising a 0.250% aqueous solution of polyvinyl alcohol. The creping adhesive is delivered to the Yankee surface at a rate of 0.1% adhesive solids based on the dry weight of the web.

The fiber consistency is increased to about 98% before the web is dry creped from the Yankee with a doctor blade. The doctor blade has a bevel angle of about 20 degrees and is positioned with respect to the Yankee dryer to provide an impact angle of about 76 degrees. The Yankee dryer is operated at a temperature of about 300oF and a speed of about 800 fpm (feet per minute) (about 244 meters per minute). The paper is wound in a roll using a surface driven reel drum having a surface speed of about 680 fpm (about 207 meters per minute), thus resulting in a crepe of about 15%.

After the doctor blade, the web is calendared across all its width with a steel to rubber calendar roll operating at a loading of 450 psi.

Resulting tissue has a basis weight of about 22 g/m2; a 1-ply total dry tensile between 280 and 320 g/in, a 1-ply wet burst between 45 and 65 g/in and a 2-ply caliper of about 0.020 inches.

Resulting tissue is then plied together with a like sheet to form a two-ply, creped, pattern densified tissue so that the acacia fibers face the outside. The resulting two-ply tissue has a) a total basis weight of about 42-45 g/m2; b) a 2-ply total dry tensile between 550 and 600 g/in; c) a 2-ply wet burst between 90 and 120 g/in; and d) a 4-ply caliper of about 0.028 inches.

Example 4

This Example illustrates a process incorporating a preferred embodiment of the present invention using the pilot scale Fourdrinier to make a toilet tissue product. An aqueous slurry of Northern Softwood Kraft (NSK) of about 3% consistency is made up using a conventional pulper and the furnish is passed through a stock pipe toward the headbox of the Fourdrinier.

In order aid in delivering a temporary wet strength to the finished product, a 1% dispersion of Cytec's Parez 750C is prepared and is added to the NSK stock pipe at a rate sufficient to deliver 0.2% of the resin based on the dry weight of the ultimate paper. The absorption of the temporary wet strength resin is enhanced by passing the treated slurry through an in-line mixer.

The NSK slurry furnish is diluted with white water to about 0.2% consistency at the fan pump.

An aqueous slurry of Acacia bleached kraft fibrous pulp (from PT Tel - Indonesia) of about 3% by weight is made up using a conventional repulper and the furnish is passed through a stock pipe toward the headbox of the Fourdrinier. The Acacia furnish has a weighted average fiber length of 0.66mm and a coarseness of 7.1 mg/100m. In order to aid in delivering temporary

wet strength to the finished product, the 1% dispersion of Cytec's Parez 750C is also added to the Acacia stock pipe at a rate sufficient to deliver 0.05% of the resin based on the dry weight of the ultimate paper. The absorption of the temporary wet strength resin is enhanced by passing the treated slurry through an in-line mixer. The Acacia slurry furnish passes to the second fan pump where it is diluted with white water to a consistency of about 0.2%.

The slurries of NSK and acacia are directed into a multi-channeled headbox suitably equipped with layering leaves to maintain the streams as separate layers until discharged onto a traveling Fourdrinier wire. A three-chambered headbox is used. The acacia slurry containing 70% of the dry weight of the ultimate paper is directed to the chambers leading to the outer layers, while the NSK slurry comprising 30% of the dry weight of the ultimate paper is directed to the chamber leading to the central layer.

The NSK and acacia slurries are combined at the discharge of the headbox into a composite slurry and the composite slurry is discharged onto the traveling Fourdrinier wire and is dewatered assisted by a deflector and vacuum boxes.

The embryonic wet web is transferred from the Fourdrinier wire, at a fiber consistency of about 15% at the point of transfer, to a patterned drying fabric. The drying fabric is designed to yield a pattern-densified tissue with discontinuous low-density deflected areas arranged within a continuous network of high density (knuckle) areas. This drying fabric is formed by casting an impervious resin surface onto a fiber mesh supporting fabric. The supporting fabric is a 45 x 52 filament, dual layer mesh. The thickness of the resin cast is about 10 mil above the supporting fabric. The knuckle area is about 40% and the open cells remain at a frequency of about 78 per square inch.

Further de-watering is accomplished by vacuum assisted drainage until the web has a fiber consistency of about 30%. While remaining in contact with the patterned forming fabric, the patterned web is pre-dried by air blow-through pre-dryers to a fiber consistency of about 65% by weight. The semi-dry web is then transferred to the Yankee dryer and adhered to the surface of the Yankee dryer with a sprayed creping adhesive comprising a 0.125% aqueous solution of polyvinyl alcohol. The creping adhesive is delivered to the Yankee surface at a rate of 0.1% adhesive solids based on the dry weight of the web. The fiber consistency is increased to about 98% before the web is dry creped from the Yankee with a doctor blade.

The doctor blade has a bevel angle of about 25 degrees and is positioned with respect to the Yankee dryer to provide an impact angle of about 81 degrees. The Yankee dryer is operated at a temperature of about 350°F (177°C) and a speed of about 800 fpm (feet per minute) (about 244 meters per minute). The paper is wound in a roll using a surface driven reel drum having a surface speed of about 656 feet per minute. In a free span between the doctor blade and the reel in

a position at which the web is essentially horizontal, an applicator comprising an extrusion slot applies an aqueous dispersion of DEEDMAMS having 44% cationic actives onto the top side of the tissue web such that the actives are uniformly distributed onto the tissue web surface. A sufficient flow of the DEEDMAMS slurry is maintained so that 1% DEEDMAMS is applied to the tissue web surface.

The resulting tissue paper web is converted into a single-ply toilet tissue paper product using a conventional tissue winding stand. The finished product has a basis weight of about 21 lb/3000ft2; a total dry tensile of 450 g/in and a density of 0.065 g/cm^3. A comparative product is made in the same manner as this example except that a Eucalyptus bleached kraft fibrous pulp is substituted for the Acacia bleached kraft fiberous pulp. The Eucalyptus pulp furnish has a fiber length of 0.73mm and a coarseness of 8.0 mg/100m. The resultant tissue paper using the comparative furnish is judged less soft by a panel of expert judges.

Example 5

Example 4 is repeated except that the furnish flow rates are adjusted in order to reduce the basis weight of the fibrous web in order to make a two ply tissue web product. Preparation of the two ply product is completed by simultaneously unwinding two rolls of fibrous web combining them into a two-ply bath by a narrow, approximately ½" stripe of pressure sensitive adhesive which allows the plies to maintain their ability to slip relative to one another. The combining is completed so that the respective Yankee-side surfaces of each ply contact each other. The finished product has a basis weight of about 28 lb/3000ft2; a total dry tensile of 500g/in and a density of 0.055 g/cm^3. Again, a comparative product is made in the same manner as this example except that the Eucalyptus bleached kraft fibrous pulp is substituted for the Acacia bleached kraft fibrous pulp. Again, the resultant tissue paper using the comparative furnish is judged less soft by a panel of expert judges.

While particular embodiments and/or individual features of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made. Further, all combinations of embodiments and features which are possible, can result in preferred executions of the invention. Therefore, the appended claims are intended to cover all such changes and modifications that are within this invention.

WHAT IS CLAIMED IS:

1. A through-air dried fibrous structure characterized by comprising:
   a. a short fiber furnish comprising a short fiber having a length of from 0.4 mm and 1.2 mm and a coarseness of from 3.0 mg/100 m to 7.5 mg/100m, and
   b. a physical property ingredient selected from the group consisting of permanent wet strength resins, chemical softeners and mixtures thereof.

2. The through-air dried fibrous structure according to Claim 1 wherein said short fiber is characterized by comprising cellulose.

3. The through-air dried fibrous structure according to Claim 2 wherein the short fiber is derived from a fiber source selected from the group consisting of: Acacia , Eucalyptus, Maple, Oak , Aspen , Birch , Cottonwood , Alder , Ash , Cherry , Elm , Hickory , Poplar , Gum , Walnut , Locust , Sycamore , Beech , Catalpa , Sassafras , Gmelina , Albizia , Anthocephalus , Magnolia , Bagasse, Flax, Hemp, Kenaf, and mixtures thereof.

4. The through-air dried fibrous structure according to any one of the preceding Claims wherein the fibrous structure further comprises a long fiber furnish comprising a long fiber having a length greater than 1.2 mm.

5. The through-air dried fibrous structure according to any of the preceding Claims characterized by the fibrous structure comprising at least 10% by weight of the total fiber composition of said short fiber furnish.

6. The through-air dried fibrous structure according to any of the preceding Claims characterized by the fibrous structure having a basis weight greater than 12 g/m^2 to 120 g/m^2.

7. The through-air dried fibrous structure according to any of the preceding Claims characterized by the fibrous structure having a wet burst strength greater than 25 g/in.

8. The through-air dried fibrous structure according to any of the preceding Claims characterized by the fibrous structure comprising two or more fibrous furnish layers.

9. The through-air dried fibrous structure according to any of the preceding Claims wherein said physical property ingredient comprises a permanent wet strength resin comprising a polyamide-epichlorohydrin resin and/or a chemical softener selected from a group consisting of quaternary ammonium compounds, silicones, emollient lotion compounds and mixtures thereof.

10. A one-ply or multi-ply sanitary tissue product comprising a fibrous structure according to any of the preceding Claims.

11. A process for making a through-air dried fibrous structure according to any of Claims 1-9 characterized by comprising the steps of:

a. preparing a fibrous furnish comprising a short fiber furnish comprising a short fiber having a length of from 0.4 mm to 1.2 mm and a coarseness of from 3.0 mg/100 m to 7.5 mg/100 m, by mixing the short fiber with water to form the short fiber furnish;
b. depositing the fibrous furnish on a foraminous forming surface to form an embryonic fibrous web; preferably wherein said embryonic web is formed from two or more furnish layers;
c. through-air drying said embryonic fibrous web such that the through-air dried fibrous structure is formed;

characterized by adding to said fibrous furnish and/or said embryonic fibrous web and/or said through-air dried fibrous structure a permanent wet strength resin and/or a chemical softener.

INTERNATIONAL SEARCH REPORT

	Ir tional Application No
	PCT/US2004/005449

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 D21H21/14 D21H17/72 D21H23/04 D21H23/24
//D21H11:00,15:02,21:20,21:22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 D21H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)
EPO-Internal, PAPERCHEM

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99/25924 A (KIMBERLY CLARK CO) 27 May 1999 (1999-05-27) the whole document	1-6,8-11
Y		1-6,8-11
X	US 2002/084048 A1 (HURST STEPHEN A ET AL) 4 July 2002 (2002-07-04) the whole document	1-6,8-11
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A	US 5 785 813 A (SHANKLIN GARY LEE ET AL) 28 July 1998 (1998-07-28)	

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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