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(54) **SOFT AND STRONG ENGINEERED TISSUE**

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(57) **ABSTRACT**

The disclosure provides tissue webs, and products incorporating the same, where the webs comprise two or more layers and have refined fibers selectively incorporated into one of the layers to provide a sheet that is both durable and soft. More specifically the disclosure provides soft and durable tissue webs comprising at least about 1 percent refined fiber by weight of the web incorporated into the air contacting layer of a multi-layered tissue web.

SOFT AND STRONG ENGINEERED TISSUE

BACKGROUND

[0001] Tissue products, such as facial tissues, paper towels, bath tissues, napkins, and other similar products, are designed to include several important properties. For example, the products should have good bulk, a soft feel, and should have good strength and durability. Unfortunately, however, when steps are taken to increase one property of the product, other characteristics of the product are often adversely affected.

[0002] To achieve the optimum product properties, tissue products are typically formed, at least in part, from pulps containing wood fibers and often a blend of hardwood and softwood fibers to achieve the desired properties. Typically when attempting to optimize surface softness, as is often the case with tissue products, the papermaker will select the fiber furnish based in part on fiber length, aspect ratio and thickness of the fiber cell wall. Unfortunately, the need for softness is balanced by the need for durability. Durability in tissue products may be defined in terms of tensile strength, burst strength and tear strength. Typically tear strength and burst strength have a positive correlation with tensile strength while tensile strength, and thus durability, and softness are inversely related. Thus the paper maker is continuously challenged with the need to balance the need for softness with a need for durability. Unfortunately, tissue paper durability generally decreases as the average fiber length is reduced. Therefore, simply reducing the pulp average fiber length can result in an undesirable trade-off between product softness and product durability.

[0003] One approach to balancing softness and strength has been to form a single ply product having three layers. The outer layers usually contain unrefined hardwood fibers while the inner layer contains refined softwood fibers to improve durability, strength and bending stiffness. Although these products may be soft due to the presence of hardwood fibers, they also tend to generate a significant level of slough. Thus, it would be desirable to provide a process, system and product that is capable of providing a high degree of softness and strength, with reduced amounts of sloughing. Furthermore, a layered tissue product that reveals reduced sloughing with a minimal or negligible effect upon softness levels would be desirable.

SUMMARY

[0004] It has now been discovered that refined fibers and particularly refined fibers having a low freeness, such as fibers having a Canadian Standard Freeness less than about 550 mL, measured in accordance with TAPPI Standard T 227 OM-94 (Canadian Standard Method), and more preferably less than about 500 mL, may be selectively incorporated into a multi-layered tissue web to yield webs that are strong, durable and soft. The benefit of adding refined fibers is particularly acute when the fibers are selectively incorporated into one layer of a multi-layered web and particularly the air contacting layer (also referred to as the non-fabric contacting layer). Surprisingly the benefits of selectively incorporating refined fibers into a multi-layered tissue structure are achieved even when refined fibers are substituted for unrefined conventional papermaking fibers in relatively modest amounts, such as less than about 40 percent by weight of the web, and in certain instances less than about 30 percent, and when the fabric contacting layer of the web is substantially free of refined fibers.

[0005] Accordingly, in certain embodiments, the present disclosure provides a multi-layered tissue web comprising a fabric contacting fibrous layer and a non-fabric contacting fibrous layer, wherein the fabric contacting fibrous layer consists essentially of unrefined conventional papermaking fibers and the non-fabric contacting fibrous layer comprises refined fibers. Preferably the fabric contacting layer is substantially free of refined fibers and the tissue web comprises from about 1 to about 40 percent by weight refined fibers. In a particularly preferred embodiment the fabric contacting fibrous layer comprises unrefined softwood kraft fibers and the air contacting fibrous layer comprises refined hardwood kraft fibers having a freeness less than about 550 mL.

[0006] In yet other embodiments the present disclosure provides a multi-layered tissue web comprising a fabric contacting fibrous layer and an air contacting fibrous layer, wherein the fabric contacting fibrous layer is substantially free of refined fibers and the air contacting fibrous layer comprises from about 1 to about 40 percent by weight refined fibers, the tissue web having a basis weight greater than about 35 gsm, a geometric mean tensile greater than about 800 g/3" and geometric mean slope of less than about 6.0 kgf.

[0007] In still other embodiments the present disclosure provides a method of forming a tissue web comprising the steps of dispersing a fiber to form a first fiber slurry, refining the first fiber slurry to a freeness less than about 550 mL, dispersing a conventional papermaking pulp to form a second fiber slurry, depositing the second fiber slurry onto a forming fabric, depositing the first fiber slurry adjacent to the second fiber slurry to form a wet web, dewatering the wet web to a consistency of from about 20 to about 30 percent, and drying the wet web to a consistency of greater than about 90 percent thereby forming a tissue web.

DEFINITIONS

[0008] As used herein the term “refined fibers” refers to any cellulosic fibrous material derived from wood and non-wood plants, including without limitation hardwood, softwood, cotton, bagasse, straw, bamboo and hemp, that has been chemically or mechanically treated.

[0009] As used herein the term “freeness” refers to the Canadian Standard Freeness (CSF) determined in accordance with TAPPI Standard T 227 OM-94 and is reported in units of milliliters (mL).

[0010] As used herein the term “average fiber length” refers to the length weighted average length of fibers determined utilizing a Kajaani fiber analyzer model No. FS-100 available from Kajaani Oy Electronics, Kajaani, Finland. According to the test procedure, a pulp sample is treated with a macerating liquid to ensure that no fiber bundles or shives are present. Each pulp sample is disintegrated into hot water and diluted to an approximately 0.001 percent solution. Individual test samples are drawn in approximately 50 to 100 ml portions from the dilute solution when tested using the standard Kajaani fiber analysis test procedure. The weighted average fiber length may be expressed by the following equation:

$$\sum_{x_i=0}^{k} (x_i \times n_i)/n$$

where k=maximum fiber length
x_i=fiber length
n_i=number of fibers having length x_i
n=total number of fibers measured.

[0011] As used herein the term "geometric mean tensile" (GMT) refers to the square root of the product of the MD tensile strength and CD tensile strength of the web, which are measured as described in the Test Method section.

[0012] As used herein, the term "slope" refers to slope of the line resulting from plotting tensile versus stretch and is an output of the MTS TestWorks™ in the course of determining the tensile strength as described in the Test Method section. Slope is reported in the units of grams (g) per unit of sample width (inches) and is measured as the gradient of the least-squares line fitted to the load-corrected strain points falling between a specimen-generated force of 70 to 157 grams (0.687 to 1.540 N) divided by the specimen width. Slopes are generally reported herein as having units of grams per 3 inch sample width or g/3".

[0013] As used herein, the term "geometric mean slope" (GM Slope) generally refers to the square root of the product of machine direction slope and cross-machine direction slope.

[0014] As used herein the term "Machine Direction Durability" generally refers to the ability of the web to resist crack propagation initiated by defects in the web and is calculated from the MD Tensile Index (calculated by dividing the MD Tensile Strength by the basis weight) and MD stretch (output of the MTS TestWorks™ in the course of determining the tensile strength as described in the Test Method section) according to the formula:

$$\text{Machine Direction Durability} = 0.6(\text{MD Tensile Index}^{0.74} + \text{MD Stretch}^{0.58})$$

[0015] As used herein, the term "stiffness index" refers to the quotient of the geometric mean slope (having units of kgf) divided by the geometric mean tensile strength (having units of g/3") multiplied by 1,000.

[0016] As used herein, the term "caliper" is the representative thickness of a single sheet (caliper of tissue products comprising two or more plies is the thickness of a single sheet of tissue product comprising all plies) measured in accordance with TAPPI test method T402 using an EMVECO 200-A Microgage automated micrometer (EMVECO, Inc., Newberg, Oreg.). The micrometer has an anvil diameter of 2.22 inches (56.4 mm) and an anvil pressure of 132 grams per square inch (per 6.45 square centimeters) (2.0 kPa).

[0017] As used herein, the term "basis weight" generally refers to the bone dry weight per unit area of a tissue and is generally expressed as grams per square meter (gsm). Basis weight is measured using TAPPI test method T-220.

[0018] As used herein, the term "sheet bulk" generally refers to the quotient of the sheet caliper expressed in microns, divided by the basis weight, expressed in grams per square meter. The resulting sheet bulk is expressed in cubic centimeters per gram.

[0019] As used herein, the term "tissue product" generally refers to various paper products, such as facial tissue, bath tissue, paper towels, napkins, and the like. Normally, the basis weight of a tissue product of the present invention is less than about 80 grams per square meter (gsm), in some embodiments less than about 60 gsm, and in some embodiments, between about 10 to about 60 gsm.

[0020] As used herein, the term "layer" refers to a plurality of strata of fibers, chemical treatments, or the like, within a ply.

[0021] As used herein, the terms "layered tissue web," "multi-layered tissue web," "multi-layered web," and "multi-layered paper sheet," generally refer to sheets of paper prepared from two or more layers of aqueous papermaking furnish which are preferably comprised of different fiber types. The layers are preferably formed from the deposition of separate streams of dilute fiber slurries, upon one or more endless foraminous screens. If the individual layers are initially formed on separate foraminous screens, the layers are subsequently combined (while wet) to form a layered composite web.

[0022] As used herein, the term "ply" refers to a discrete product element. Individual plies may be arranged in juxtaposition to each other. The term may refer to a plurality of web-like components such as in a multi-ply facial tissue, bath tissue, paper towel, wipe, or napkin.

DETAILED DESCRIPTION

[0023] In general, the present disclosure relates to tissue webs, and products produced therefrom, comprising conventional papermaking fibers and refined fibers. It has been discovered that by replacing some of the conventional papermaking fibers in the tissue web with refined fibers, and more specifically conventional fibers disposed in the air contacting layer of a multi-layer tissue structure, that a stronger and more durable web may be produced without sacrificing softness.

[0024] Despite the tendency of refined fibers to have high aspect ratios and short average fiber lengths it has now been surprisingly discovered that they may be a satisfactory replacement for conventional papermaking fibers in tissue webs. In particular, it has been surprisingly discovered that selectively incorporating refined fibers into the air contacting layer of a multi-layered tissue structure actually increases tensile strength without negatively effecting stiffness. In fact, in certain instances, the increase in tensile may be accompanied by only a slight increase in geometric mean slope, resulting in a web having a lower stiffness index. Previously, it was believed that the greatest benefit was achieved when the long fiber fraction in the middle, or non-air contacting surface, was refined. However, it has now been discovered that the beneficial effect on tensile and stiffness is particularly acute when the refined fibers are substituted for convention papermaking fibers in the air contacting layer of a multi-layered web and especially when the air contacting layer comprises refined shorter length fibers. The benefits of refining a portion of the short fiber length fraction of the papermaking furnish and selectively incorporating the fibers into the air contacting layer of a multi-layered web are illustrated in the table below.

TABLE 1

	Refined fiber (wt %)	Basis Wt. (gsm)	GMT (g/3")	MD Tensile (g/3")	GM Slope (kgf)	stiffness index	MD Durability Index
Fabric Layer	EHWK 30%	36.3	994	1252	4.70	4.73	11.73

TABLE 1-continued

	Refined fiber (wt %)	Basis Wt. (gsm)	GMT (g/3")	MD Tensile (g/3")	GM Slope (kgf)	stiffness index	MD Durability Index
Air Layer	EHWK 30%	36.6	1119	1485	4.60	4.11	12.79

[0025] The refined fibers are preferably derived from either wood or non-wood fibers and preferably comprise a portion of the short fiber length fraction of the overall papermaking furnish. More preferably the refined fibers are derived from wood or non-wood fibers having an average fiber length less than about 2.0 mm, and more preferably less than about 1.7 mm, such as from about 0.5 to about 1.5 mm.

[0026] In one embodiment the refined fibers are derived from wood fibers and more preferably hardwood fibers and still more preferably hardwood fibers, such as, but not limited to, eucalyptus, maple, birch, aspen, and the like. In a particularly preferred embodiment the refined fibers comprise refined eucalyptus hardwood kraft pulps ("EHWK") having a freeness less than about 500 mL and more preferably less than about 475 mL, such as from about 300 to about 475 mL.

[0027] In other embodiments the refined fibers are derived from non-wood fibers, such as, but not limited to, bamboo, cotton, straws, bagasse and kenaf. In a particularly preferred embodiment the refined fibers are refined bamboo fibers having a freeness less than about 620 mL and more preferably less than about 600 mL, such as from about 300 to about 600 mL. In some embodiments, the bamboo fiber is derived from temperate bamboos of the *Phyllostachys* species, for example *Phyllostachys heterocycla pubescens*, also known as Moso Bamboo. However, it is to be understood that the compositions disclosed herein are not limited to containing any one bamboo fiber and may comprise a plurality of fibers of different species.

[0028] Regardless of the origin of the fiber, the refined fibers have a low freeness and have preferably been subjected to mechanical forces, such as by beating or refining, in the presence of water. Refining and beating methods are well known in the art and typically involve providing a dilute fiber slurry, such as a fiber slurry having a consistency from about 1 to about 10 percent solids, and subjecting the fiber slurry to mechanical forces applied by a pair of opposed plates. Refining of fibers in this manner generally results in cutting and shortening of fibers, the creation of fines, external fibrillation, swelling, alteration of fiber shape by curling, creating nodes, or kinks and the redistribution of hemicelluloses from the interior of the fiber to the exterior. As a result, after refining the fibers are generally collapsed (flattened) and made more flexible, and their bonding surface area is increased.

[0029] In one particularly preferred embodiment the refined fiber comprises refined hardwood fiber and more preferably EHWK that has been refined using a double disc refiner having bar width of segments from about 2.4 about 3.5 mm, a refining intensity (measured as specific edge load "SEL") from about 0.5 to about 1.5 Jim and a refining consistency of about 4.0 to about 5.5 percent. The refined EHWK preferably has a freeness less than about 500 mL and more preferably less than about 475 mL, such as from about 300 to about 475 mL.

[0030] Regardless of the origin of the fiber, refined fibers preferably have an average fiber length greater than about 0.5 mm, such as from about 0.5 to about 2.0 mm and more preferably from about 0.7 to about 1.5 mm. The refined fibers preferably have a freeness less than about 550 mL and more preferably less than about 500 mL, such as from about 300 to about 500 mL.

[0031] In certain embodiments the refined fibers may be blended with one or more conventional papermaking fibers and the blended pulp fibers may be selectively incorporated into the air contacting layer of a multi-layered tissue web. In such embodiments the resulting web comprises at least about 10 percent by weight, refined fibers, and more preferably at least about 20 percent, such as from about 20 to about 40 percent. The blended pulp fibers preferably have a freeness less than about 550 mL, and more preferably less than about 500 mL, such as from about 300 to about 500 mL.

[0032] Regardless of the species or particular average fiber length, multi-layered tissue webs of the present disclosure comprise at least about 10 percent, by total weight of the web, and more preferably at least about 20 percent and still more preferably from about 10 to about 40 percent refined fiber where the refined fibers are disposed in the air contacting layer of a multi-layered web.

[0033] Further, it is preferred that the refined fibers are selectively incorporated into the multi-layered web such that the fibers are disposed in the air contacting layer and that the fabric contacting layer is substantially free from refined fibers. It should be understood that, when referring to a layer that is substantially free of refined fibers, negligible amounts of the fibers may be present therein, however, such small amounts often arise from the refined fibers applied to an adjacent layer, and do not typically substantially affect the softness or other physical characteristics of the web.

[0034] Conventional papermaking fibers may comprise pulp fibers formed by a variety of pulping processes, such as kraft pulp, sulfite pulp, thermomechanical pulp, and the like. Further, the wood fibers may be any high-average fiber length wood pulp, low-average fiber length wood pulp, or mixtures of the same. One example of suitable high-average length pulp fibers include softwood fibers, such as, but not limited to, northern softwood, southern softwood, redwood, red cedar, hemlock, pine (e.g., southern pines), spruce (e.g., black spruce), combinations thereof, and the like. One example of suitable low-average length pulp fibers include hardwood fibers, such as, but not limited to, eucalyptus, maple, birch, aspen, and the like. In certain instances, eucalyptus fibers may be particularly desired to increase the softness of the web. Eucalyptus fibers can also enhance the brightness, increase the opacity, and change the pore structure of the web to increase its wicking ability. Moreover, if desired, secondary fibers obtained from recycled materials may be used, such as fiber pulp from sources such as, for example, newsprint, reclaimed paperboard, and office waste.

[0035] In a particularly preferred embodiment refined fibers are utilized in the tissue web such that the total amount of high average fiber length wood fibers, such as softwood fibers and more specifically Northern softwood kraft fibers, may be reduced. In this manner, the amount of NSWK may be reduced without sacrificing strength and without negatively effecting stiffness. In one particular embodiment, refined fibers are incorporated into a multi-layered web having a middle layer disposed between an air contacting layer and a fabric contacting layer where the air contacting layer comprises refined fibers, the middle layer comprises softwood fibers and the fabric contacting layer comprises hardwood fibers and is substantially free from refined fibers. In such embodiments the refined fiber may be added to the air contacting layer such that the layer comprises greater than about 1 percent by total weight of the multi-layered web, and more preferably greater than about 10 percent, and still more preferably greater than about 20 percent, such as from about to 20 to about 40 percent.

[0036] In addition to varying the amount of refined fiber within the web, as well as the amount in any given layer, the physical properties of the web may be varied by specifically selecting particular layer(s) for incorporation of the refined fiber fibers. It has now been discovered that the greatest increase in tensile is achieved by selectively incorporating the refined fiber fibers in a multi-layered web such that the layer comprising refined fiber is not brought into contact with the forming fabric during formation of the web.

[0037] In a particularly preferred embodiment, the present disclosure provides a tissue web having enhanced tensile strength without a corresponding increase in stiffness, where the multi-layered tissue web comprises fabric and air contacting layers, wherein the fabric contacting fibrous layer comprises conventional papermaking fibers and is substantially free from refined fiber and the air contacting fibrous layer comprises conventional papermaking fibers and refined fibers. Preferably the webs have a geometric mean tensile strength greater than about 500 g/3", such as from about 500 to about 1000 g/3", and more preferably from about 700 to about 800 g/3", yet have a stiffness index less than about 10.0, more preferably less than about 9.0, and still more preferably less than about 8.0, such as from about 5.0 to about 8.0.

[0038] In still other embodiments, the present disclosure provides tissue webs having enhanced bulk, softness and durability Improved durability, such as increased machine and cross-machine direction stretch (MD Stretch and CD Stretch), and improved softness may be measured as a reduction in the slope of the tensile-strain curve (measured as GM Slope) or the stiffness index. For example, tissue webs prepared as described herein generally have a GM Slope less than about 10.0 kgf, such as from about 6.0 to about 10.0 kgf and more preferably from about 6.5 to about 7.5 kgf. The GM Slopes are achieved at relatively modest tensile strengths, such as a GMT from about 700 to about 900 g/3", yielding stiffness indexes from about 6.0 to about 9.0.

[0039] Similarly, webs may also have MD Stretch from greater than about 12 percent and more preferably greater than about 15 percent, such as from about 15 to about 20 percent, yielding webs having Machine Direction Durability greater than about 8.0 and more preferably greater than about 9.0, such as from about 9.0 to about 12.0.

[0040] Webs prepared as described herein may be converted into either single or multi-ply rolled tissue products that have improved properties over the prior art. In one embodiment the present disclosure provides a rolled tissue product comprising a spirally wound tissue web having at least two layers, wherein the air-contacting layer comprises at least about 10 percent by weight of the web refined fibers and wherein the tissue web has a bone dry basis weight greater than about 35 gsm, a sheet bulk greater than about 15 cc/g and a stiffness index less than about 9.0.

[0041] The tissue webs may also be incorporated into tissue products that may be either single- or multi-ply, where one or more of the plies may be formed by a multi-layered tissue web having refined fiber selectively incorporated in one of its layers. In one embodiment the tissue product is constructed such that the refined fibers are brought into contact with the user's skin in-use. For example, the tissue product may comprise two multi-layered through-air dried webs wherein each web comprises a fabric contacting fibrous layer substantially free from refined fiber and an air contacting fibrous layer comprising refined fiber. The webs are plied together such that the outer surface of the tissue product is formed from the fabric contacting fibrous layers of each web, such that the surface brought into contact with the user's skin in-use comprises refined fiber.

[0042] If desired, various chemical compositions may be applied to one or more layers of the multi-layered tissue web to further enhance softness and/or reduce the generation of lint or slough. For example, in some embodiments, a wet strength agent can be utilized, to further increase the strength of the tissue product when wet. As used herein, a "wet strength agent" is any material that when added to pulp fibers can provide a resulting web or sheet with a wet geometric tensile strength to dry geometric tensile strength ratio in excess of about 0.1. Typically these materials are termed either "permanent" wet strength agents or "temporary" wet strength agents. As is well known in the art, temporary and permanent wet strength agents may also sometimes function as dry strength agents to enhance the strength of the tissue product when dry.

[0043] Wet strength agents may be applied in various amounts depending on the desired characteristics of the web. For instance, in some embodiments, the total amount of wet strength agents added can be between about 1 to about 60 pounds per ton (lbs/T), in some embodiments, between about 5 to about 30 lbs/T, and in some embodiments, between about 7 to about 13 lbs/T of the dry weight of fibrous material. The wet strength agents can be incorporated into any layer of the multi-layered tissue web.

[0044] A chemical debonder can also be applied to soften the web. Specifically, a chemical debonder can reduce the amount of hydrogen bonds within one or more layers of the web, which results in a softer product. Depending on the desired characteristics of the resulting tissue product, the debonder can be utilized in varying amounts. For example, in some embodiments, the debonder can be applied in an amount between about 1 to about 30 lbs/T, in some embodiments between about 3 to about 20 lbs/T, and in some embodiments, between about 6 to about 15 lbs/T of the dry weight of fibrous material. The debonder can be incorporated into any layer of the multi-layered tissue web.

[0045] Any material capable of enhancing the soft feel of a web by disrupting hydrogen bonding can generally be used as a debonder in the present invention. In particular, as stated above, it is typically desired that the debonder possess a cationic charge for forming an electrostatic bond with anionic groups present on the pulp. Some examples of suitable cationic debonders can include, but are not limited to, quaternary ammonium compounds, imidazolinium compounds, bis-imidazolinium compounds, diquaternary ammonium compounds, polyquaternary ammonium compounds, ester-functional quaternary ammonium compounds (e.g., quaternized fatty acid trialkanolamine ester salts), phospholipid derivatives, polydimethylsiloxanes and related cationic and nonionic silicone compounds, fatty and carboxylic acid derivatives, mono and polysaccharide derivatives, polyhydroxy hydrocarbons, etc. For instance, some suitable debonders are described in U.S. Pat. Nos. 5,716,498, 5,730,839, 6,211,139, 5,543,067, and WO/0021918, all of which are incorporated herein in a manner consistent with the present disclosure.

[0046] Still other suitable debonders are disclosed in U.S. Pat. Nos. 5,529,665 and 5,558,873, both of which are incorporated herein in a manner consistent with the present disclosure. In particular, U.S. Pat. No. 5,529,665 discloses the use of various cationic silicone compositions as softening agents.

[0047] Tissue webs of the present disclosure can generally be formed by any of a variety of papermaking processes known in the art. Preferably the tissue web is formed by through-air drying and can be either creped or uncreped. For example, a papermaking process of the present disclosure can utilize adhesive creping, wet creping, double creping, embossing, wet-pressing, air pressing, through-air drying, creped through-air drying, uncreped through-air drying, as well as other steps in forming the paper web. Some examples of such techniques are disclosed in U.S. Pat. Nos. 5,048,589, 5,399,412, 5,129,988 and 5,494,554 all of which are incorporated herein in a manner consistent with the present disclosure. When forming multi-ply tissue products, the separate plies can be made from the same process or from different processes as desired.

[0048] For example, in one embodiment, tissue webs may be creped through-air dried webs formed using processes known in the art. To form such webs, an endless traveling forming fabric, suitably supported and driven by rolls, receives the layered papermaking stock issuing from headbox. A vacuum box is disposed beneath the forming fabric and is adapted to remove water from the fiber furnish to assist in forming a web. From the forming fabric, a formed web is transferred to a second fabric, which may be either a wire or a felt. The fabric is supported for movement around a continuous path by a plurality of guide rolls. A pick up roll designed to facilitate transfer of web from fabric to fabric may be included to transfer the web.

[0049] Preferably the formed web is dried by transfer to the surface of a rotatable heated dryer drum, such as a Yankee dryer. The web may be transferred to the Yankee directly from the throughdrying fabric or, preferably, transferred to an impression fabric which is then used to transfer the web to the Yankee dryer. In accordance with the present disclosure, the creping composition of the present disclosure may be applied topically to the tissue web while the web is traveling on the fabric or may be applied to the surface of the dryer drum for transfer onto one side of the tissue web. In this manner, the creping composition is used to adhere the tissue web to the dryer drum. In this embodiment, as the web is carried through a portion of the rotational path of the dryer surface, heat is imparted to the web causing most of the moisture contained within the web to be evaporated. The web is then removed from the dryer drum by a creping blade. The creping web as it is formed further reduces internal bonding within the web and increases softness. Applying the creping composition to the web during creping, on the other hand, may increase the strength of the web.

[0050] In another embodiment the formed web is transferred to the surface of the rotatable heated dryer drum, which may be a Yankee dryer. The press roll may, in one embodiment, comprise a suction pressure roll. In order to adhere the web to the surface of the dryer drum, a creping adhesive may be applied to the surface of the dryer drum by a spraying device. The spraying device may emit a creping composition made in accordance with the present disclosure or may emit a conventional creping adhesive. The web is adhered to the surface of the dryer drum and then creped from the drum using the creping blade. If desired, the dryer drum may be associated with a hood. The hood may be used to force air against or through the web.

[0051] In other embodiments, once creped from the dryer drum, the web may be adhered to a second dryer drum. The second dryer drum may comprise, for instance, a heated drum surrounded by a hood. The drum may be heated from about 25 to about 200° C., such as from about 100 to about 150° C.

[0052] In order to adhere the web to the second dryer drum, a second spray device may emit an adhesive onto the surface of the dryer drum. In accordance with the present disclosure, for instance, the second spray device may emit a creping composition as described above. The creping composition not only assists in adhering the tissue web to the dryer drum, but also is transferred to the surface of the web as the web is creped from the dryer drum by the creping blade.

[0053] Once creped from the second dryer drum, the web may, optionally, be fed around a cooling reel drum and cooled prior to being wound on a reel.

[0054] For example, once a fibrous web is formed and dried, in one aspect, the creping composition may be applied to at least one side of the web and the at least one side of the web may then be creped. In general, the creping composition may be applied to only one side of the web and only one side of the web may be creped, the creping composition may be applied to both sides of the web and only one side of the web is creped, or the creping composition may be applied to each side of the web and each side of the web may be creped.

[0055] Once creped the tissue web may be pulled through a drying station. The drying station can include any form of a heating unit, such as an oven energized by infra-red heat, microwave energy, hot air, or the like. A drying station may be necessary in some applications to dry the web and/or cure the creping composition. Depending upon the creping composition selected, however, in other applications a drying station may not be needed.

[0056] In other embodiments, the base web is formed by an uncreped through-air drying process such as those described, for example, in U.S. Pat. Nos. 5,656,132 and 6,017,417, both of which are hereby incorporated by reference herein in a manner consistent with the present disclosure. The uncreped through-air drying process may comprise a twin wire former having a papermaking headbox which injects or deposits a furnish of an aqueous suspension of wood fibers onto a plurality of forming fabrics, such as an outer forming fabric and an inner forming fabric, thereby forming a wet tissue web. The forming process may be any conventional forming process known in the papermaking industry. Such formation processes include, but are not limited to, Fourdriniers, roof formers such as suction breast roll formers, and gap formers such as twin wire formers and crescent formers.

[0057] The wet tissue web forms on the inner forming fabric as the inner forming fabric revolves about a forming roll. The inner forming fabric serves to support and carry the newly-formed wet tissue web downstream in the process as the wet tissue web is partially dewatered to a consistency of about 10 percent based on the dry weight of the fibers. Additional dewatering of the wet tissue web may be carried out by known paper making techniques, such as vacuum suction boxes, while the inner forming fabric supports the wet tissue web. The wet tissue web may be additionally dewatered to a consistency of at least about 20 percent, more specifically between about 20 to about 40 percent, and more specifically about 20 to about 30 percent.

[0058] The forming fabric can generally be made from any suitable porous material, such as metal wires or polymeric filaments. For instance, some suitable fabrics can include, but are not limited to, Albany 84M and 94M available from Albany International (Albany, N.Y.) Asten 856, 866, 867, 892, 934, 939, 959, or 937; Asten Synweve Design 274, all of which are available from Asten Forming Fabrics, Inc. (Appleton, Wis.); and Voith 2164 available from Voith Fabrics (Appleton, Wis.). The wet web is then transferred from the forming fabric to a transfer fabric while at a solids consistency of between about 10 to about 35 percent, and particularly, between about 20 to about 30 percent. As used herein, a "transfer fabric" is a fabric that is positioned between the forming section and the drying section of the web manufacturing process.

[0059] Transfer to the transfer fabric may be carried out with the assistance of positive and/or negative pressure. For example, in one embodiment, a vacuum shoe can apply negative pressure such that the forming fabric and the transfer fabric simultaneously converge and diverge at the leading edge of the vacuum slot. Typically, the vacuum shoe supplies pressure at levels between about 10 to about 25 inches of mercury. As stated above, the vacuum transfer shoe (negative pressure) can be supplemented or replaced by the use of positive pressure from the opposite side of the web to blow the web onto the next fabric. In some embodiments, other vacuum shoes can also be used to assist in drawing the fibrous web onto the surface of the transfer fabric.

[0060] Typically, the transfer fabric travels at a slower speed than the forming fabric to enhance the MD and CD stretch of the web, which generally refers to the stretch of a web in its cross (CD) or machine direction (MD) (expressed as percent elongation at sample failure). For example, the relative speed difference between the two fabrics can be from about 1 to about 30 percent, in some embodiments from about 5 to about 20 percent, and in some embodiments, from about 10 to about 15 percent. This is commonly referred to as "rush transfer." During "rush transfer," many of the bonds of the web are believed to be broken, thereby forcing the sheet to bend and fold into the depressions on the surface of the transfer fabric. Such molding to the contours of the surface of the transfer fabric 8 may increase the MD and CD stretch of the web. Rush transfer from one fabric to another can follow the principles taught in any one of the following patents, U.S. Pat. Nos. 5,667,636, 5,830,321, 4,440,597, 4,551,199, 4,849,054, all of which are hereby incorporated by reference herein in a manner consistent with the present disclosure. The wet tissue web is then transferred from the transfer fabric to a throughdrying fabric.

[0061] While supported by the throughdrying fabric, the wet tissue web is dried to a final consistency of about 94 percent or greater by a throughdryer. The drying process can be any noncompressive drying method which tends to preserve the bulk or thickness of the wet web including, without limitation, throughdrying, infra-red radiation, microwave drying, etc. Because of its commercial availability and practicality, throughdrying is well known and is one commonly used means for noncompressively drying the web for purposes of this invention. Suitable throughdrying fabrics include, without limitation, fabrics with substantially continuous machine direction ridges whereby the ridges are made up of multiple warp strands grouped together, such as those disclosed in U.S. Pat. No. 6,998,024. Other suitable throughdrying fabrics include those disclosed in U.S. Pat. No. 7,611,607, which is incorporated herein in a manner consistent with the present disclosure, particularly the fabrics denoted as Fred (t1207-77), Jetson (t1207-6) and Jack (t1207-12). The web is preferably dried to final dryness on the throughdrying fabric, without being pressed against the surface of a Yankee dryer, and without subsequent creping.

[0062] Additionally, webs prepared according to the present disclosure may be subjected to any suitable post processing including, but not limited to, printing, embossing, calendering, slitting, folding, combining with other fibrous structures, and the like.

Test Method

[0063] Tensile

[0064] Tensile testing was done in accordance with TAPPI test method T-576 "Tensile properties of towel and tissue products (using constant rate of elongation)" wherein the testing is conducted on a tensile testing machine maintaining a constant rate of elongation and the width of each specimen tested is 3 inches. More specifically, samples for dry tensile strength testing were prepared by cutting a 3 inches±0.05 inch (76.2 mm±1.3 mm) wide strip in either the machine direction (MD) or cross-machine direction (CD) orientation using a JDC Precision Sample Cutter (Thwing-Albert Instrument Company, Philadelphia, Pa., Model No. JDC 3-10, Serial No. 37333) or equivalent. The instrument used for measuring tensile strengths was an MTS Systems Sintech 11S, Serial No. 6233. The data acquisition software was an MTS TestWorks® for Windows Ver. 3.10 (MTS Systems Corp., Research Triangle Park, N.C.). The load cell was selected from either a 50 Newton or 100 Newton maximum, depending on the strength of the sample being tested, such that the majority of peak load values fall between 10 to 90 percent of the load cell's full scale value. The gauge length between jaws was 4±0.04 inches (101.6±1 mm) for facial tissue and towels and 2±0.02 inches (50.8±0.5 mm) for bath tissue. The crosshead speed was 10±0.4 inches/min (254±1 mm/min), and the break sensitivity was set at 65 percent. The sample was placed in the jaws of the instrument, centered both vertically and horizontally. The test was then started and ended when the specimen broke. The peak load was recorded as either the "MD tensile strength" or the "CD tensile strength" of the specimen depending on direction of the sample being tested. Ten representative specimens were tested for each product or sheet and the arithmetic average of all individual specimen tests was recorded as the appropriate MD or CD tensile strength the product or sheet in units of grams of force per 3 inches of sample. The geometric mean tensile (GMT) strength was calculated and is expressed as grams-force per 3 inches of sample width. Slope is also calculated by the tensile tester and recorded in units of kg.

EXAMPLES

[0065] Commodity pulps were obtained as follows—Eucalyptus kraft pulp ("EHWK") was obtained from Fibria, San Paulo, Brazil, Northern softwood kraft pulp ("NSWK") was obtained from Northern Pulp Nova Scotia Corporation, Abercrombie, NS, and bamboo kraft pulp was obtained from Guizhou Chitianhua Paper Co., Ltd., Guizhou, China.

Example 1

Through-Air Dried Tissue Comprising Refined Bamboo Fibers

[0066] A single ply through-air dried tissue web was made generally in accordance with U.S. Pat. No. 5,607,551, which is herein incorporated by reference in a manner consistent with the present disclosure. More specifically, from about 60 to about 100 pounds (oven dry basis) of EHWK was dispersed in a pulper at 100° F. for 25 minutes at a consistency of 3 percent before being transferred in equal parts to two machine chests and diluted to a consistency of 1 percent.

[0067] Forty pounds (oven dry basis) of bamboo kraft pulp were dispersed in a pulper at 100° F. for 25 minutes at a consistency of 3 percent before being transferred to a second machine chest and diluted to 1 percent consistency. The bamboo pulp was refined at 1.5 to 5.0 hp-days/metric ton to a freeness of about 590 mL.

[0068] To produce a layered tissue web, prior to forming each stock was further diluted to approximately 0.1 percent consistency and transferred to a 3-layer headbox in such a manner as to provide a layered sheet. The fiber compositions of the layered sheets are described in the table below. The formed web was non-compressively dewatered and rush transferred to a transfer fabric traveling at a speed about 28 percent slower than the forming fabric. The web was then transferred to a throughdrying fabric and dried.

TABLE 2

Sample	Center Layer (wt %)	Air Contacting Layer (wt %)	Fabric Contacting Layer (wt %)
1	30 EHWK	30 EHWK	40 Bamboo
2	30 EHWK	40 Bamboo	30 EHWK

[0069] The base sheet webs were converted into various bath tissue rolls. Specifically, base sheet was calendered using one or two conventional polyurethane/steel calenders comprising either a 4 or a 40 P&J polyurethane roll on the air contacting side of the sheet and a standard steel roll on the fabric contacting side. All rolled products comprised a single ply of base sheet. They physical properties of the products are summarized in the tables below.

TABLE 3

Sample	Basis Weight (gsm)	GMT (g/3")	GM Slope (kgf)	stiffness index
1	34.27	542	5.41	9.98
2	33.88	653	5.87	8.98

TABLE 4

Sample	MD Tensile (g/3")	MD Tensile Index	MD Stretch (%)	MD Durability Index
1	714.56	20.85	12.27	8.25
2	914.18	26.98	12.21	9.43

Example 2

Through-Air Dried Tissue Comprising Refined Hardwood Fibers

[0070] An uncreped through-air dried tissue was prepared substantially as described in Example 1 with the exception that the furnish blend was altered by substituting NSWK for bamboo and altering the arrangement of the fibers in the tissue as described in Table 5, below.

[0071] From about 60 to about 100 pounds (oven dry basis) of EHWK was dispersed in a pulper at 100° F. for 25 minutes at a consistency of 3 percent before being transferred in equal parts to two machine chests and diluted to a consistency of 1 percent. A portion of the EWHK pulp was refined at 1.5 to 5.0 hp-days/metric ton to a freeness of 347 mL.

[0072] The NSWK pulp fibers were dispersed in a pulper for 25 minutes at 3 percent consistency at about 100° F. The NSWK pulp was then transferred to a dump chest and subsequently diluted to approximately 0.75 percent consistency.

[0073] To produce a layered tissue web, prior to forming each stock was further diluted to approximately 0.1 percent consistency and transferred to a 3-layer headbox in such a manner as to provide a layered sheet. The fiber composition of the layered sheets is described in the table below.

TABLE 5

Sample	TAD Fabric	Center Layer (wt %)	Air Contacting Layer (wt %)	Fabric Contacting Layer (wt %)
3	High Topography	40 NSWK	30 EHWK	30 Refined EHWK
4	High Topography	40 NSWK	30 Refined EHWK	30 EHWK
5	Low Topography	40 NSWK	30 EHWK	30 Refined EHWK
6	Low Topography	40 NSWK	30 Refined EHWK	30 EHWK

[0074] The base sheet webs were converted into various bath tissue rolls. Specifically, base sheet was calendered using one or two conventional polyurethane/steel calenders comprising either a 4 or a 40 P&J polyurethane roll on the air contacting side of the sheet and a standard steel roll on the fabric contacting side. All rolled products comprised a single ply of base sheet. They physical properties of the products are summarized in the tables below.

TABLE 6

Sample	Basis Weight (gsm)	GMT (g/3")	GM Slope (kgf)	stiffness index
3	36.3	994	4.70	4.73
4	36.6	1119	4.60	4.11
5	37.3	1525	11.18	7.33
6	37.7	2059	15.19	7.38

TABLE 7

Sample	MD Tensile (g/3")	MD Tensile Index	MD Stretch (%)	MD Durability Index
3	1252	34.47	20.85	11.73
4	1485	40.60	20.82	12.79
5	1811	48.51	25.77	14.56
6	2358	62.61	26.58	16.83

Example 3

Creped Tissue Comprising Refined Hardwood Fibers

[0075] Inventive engineered tissue webs comprising selectively incorporated refined hardwood fibers were also produced by a conventional wet pressed creped process utilizing a Crescent Former. Initially, the NSWK pulp fibers were dispersed in a pulper for 25 minutes at 3 percent consistency at about 100° F. The NSWK pulp was then transferred to a dump chest and subsequently diluted to approximately 0.75 percent consistency. Similarly EHWK pulp fibers were dispersed in a pulper for 25 minutes at 3 percent consistency at 100° F. The Eucalyptus pulp slurry was then transferred to a dump chest and subsequently diluted to approximately 0.75 percent consistency. A portion of the EHWK was refined at 1.5 to 5.0 hp-days/metric ton to a freeness of 347 mL and transferred to a separate machine chest for blending and formation of a tissue web as described below.

[0076] The pulp fibers from the machine chests were pumped to the headbox at a consistency of about 0.1 percent. Pulp fibers from each machine chest were sent through separate manifolds in the headbox to create a 3-layered tissue structure. The flow rates of the stock pulp fiber slurries into the flow spreader were adjusted to give a target web basis. In those instances where a layer structure was produced, flow of stock pulp fiber slurries was controlled to provide a layer split of about 30 to about 35 percent by total weight of the tissue web EHWK fibers on both outer layers and 30 to about 40 percent NSWK or bamboo pulp fibers in the center layer. The fibers were deposited onto a felt in using a Crescent Former. The wet sheet, about 10 to 20 percent consistency, was adhered to a Yankee dryer, traveling at about 80 to 120 fpm through a nip via a pressure roll.

[0077] The consistency of the wet sheet after the pressure roll nip (post-pressure roll consistency or PPRC) was approximately 40 percent. A spray boom situated underneath the Yankee dryer sprayed a creping composition at a pressure of 60 psi at a rate of approximately 0.25 g solids/m^2 of product. The creping composition comprised 0.16 percent by weight of polyvinyl alcohol (PVOH), (Celvol™ 523 available from Celanese Chemicals, Calvert City, Ky.), 0.013 percent by weight PAE resin (Kymene™ 6500 available from Ashland, Covington, Ky.) and 0.0013 percent by weight of Resozol™ 2008 (Ashland, Covington, Ky.).

[0078] The sheet was dried to about 98 to 99 percent consistency as it traveled on the Yankee dryer and to the creping blade. The creping blade subsequently scraped the tissue sheet and a portion of the creping composition off the Yankee dryer. The creped tissue basesheet was then wound onto a core traveling at about 50 to about 100 fpm into soft rolls for converting. To produce the 2-ply facial tissue products two soft rolls of the creped tissue were rewound, calendered, and plied together so that both creped sides were on the outside of the 2-ply structure. Mechanical crimping on the edges of the structure held the plies together.

TABLE 8

Sample	Center Layer (wt %)	Air Contacting Layer (wt %)	Fabric Contacting Layer (wt %)
7	30 EHWK	30 EHWK	40 Bamboo
8	30 EHWK	40 Bamboo	30 EHWK

TABLE 9

Sample	Basis Weight (gsm)	GMT (g/3")	GM Slope (kgf)	stiffness index
7	34.27	542	5.41	9.98
8	33.88	653	5.87	8.98

TABLE 10

Sample	MD Tensile (g/3")	MD Tensile Index	MD Stretch (%)	MD Durability Index
7	714.56	20.85	12.27	8.25
8	914.18	26.98	12.21	9.43

[0079] While tissue webs and products comprising the same have been described in detail with respect to the specific embodiments thereof, it will be appreciated that those skilled in the art, upon attaining an understanding of the foregoing, may readily conceive of alterations to, variations of, and equivalents to these embodiments. Accordingly, the scope of the present invention should be assessed as that of the appended claims and any equivalents thereto.

1. A layered tissue web comprising a first air contacting layer and a second fabric contacting layer, wherein the first air contacting layer comprises from about 1 to about 40 weight percent refined fibers by weight of the web and the second fabric contacting layer is substantially free from refined fibers.

2. The layered tissue web of claim **1** having a stiffness index of less than about 10.0.

3. The layered tissue web of claim **1** having an MD Durability Index of greater than about 10.0.

4. The layered tissue web of claim **1** having a basis weight greater than about 15 gsm, a geometric mean tensile index of at least about 30 and a geometric mean slope of less than about 10.0 kgf.

5. The layered tissue web of claim **1** having a geometric mean tensile from about 700 to about 1000 g/3" and a geometric mean slope from about 6.0 to about 9.0 kgf.

6. The layered tissue web of claim **1** having a basis weight from about 15 to about 45 gsm.

7. The layered tissue web of claim **1** wherein the first air contacting layer comprises from about 5 to about 30 weight percent refined fibers by weight of the web.

8. The layered tissue web of claim **1** the refined fibers comprise refined hardwood pulp fibers selected from the group consisting of eucalyptus, maple, birch, and aspen pulps, and combinations thereof.

9. The layered tissue web of claim **1** wherein the refined fibers comprise refined nonwood fibers selected from the group consisting of bamboo, cotton, straws, bagasse and kenaf.

10. A layered tissue web comprising an air contacting layer consisting essentially of about 10 to about 40 percent refined eucalyptus hardwood kraft fibers (EHWK) by weight of the web, a middle layer comprising conventional papermaking fibers and a fabric contacting layer comprising conventional papermaking fibers, wherein the fabric contacting layer is substantially free of refined EHWK fibers.

11. The layered tissue web of claim **10** wherein the middle layer is substantially free of refined EHWK fibers.

12. The layered tissue web of claim **10** wherein the fabric contacting layer comprises hardwood fibers and the middle layer comprises softwood fibers.

13. The layered tissue web of claim **10** having a basis weight greater than about 15 gsm, a geometric mean tensile index of at least about 30 and a geometric mean slope of less than about 10.0 kg.

14. The layered tissue web of claim **10** having a stiffness index of less than about 10.0.

15. The layered tissue web of claim **10** having an MD Durability Index of greater than about 10.0.

16. The layered tissue web of claim **10** having a basis weight from about 15 to about 45 gsm, a geometric mean strength from about 700 to about 1000 g/3" and a geometric mean slope from about 6.0 to about 9.0 kgf.

17. The layered tissue web of claim **10** wherein the first air contacting layer comprises from about 5 to about 30 weight percent refined fibers by weight of the web.

18. A method of forming a layered tissue web comprising the steps of:

a. refining a first fiber;
b. dispersing the refined first fiber to form a first fiber slurry;
c. dispersing an unrefined conventional papermaking fiber to form a second fiber slurry;
d. depositing the first and second fiber slurries onto a forming fabric such that the second fiber slurry contacts the forming fabric and the first fiber slurry contacts the air to form a wet web;
e. dewatering the wet web to a consistency of from about 20 to about 30 percent; and
f. drying the wet web to a consistency of greater than about 90 percent thereby forming a dried tissue web.

19. The method of claim **18** wherein the first fiber comprises eucalyptus hardwood kraft fibers (EHWK) and the first fiber is refined to a freeness from about 300 to about 500 mL.

20. The method of claim **18** wherein the first fiber comprises bamboo fibers and the first fiber is refined to a freeness from about 300 to about 600 mL.

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