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(54) HYGRO FLAT WOVEN FABRICS, ARTICLES, AND RELATED PROCESSES

HYGRO-FLACHGEWEBE, ARTIKEL UND ZUGEHÖRIGE VERFAHREN

TISSUS TISSÉS À PLAT HYGRO, ARTICLES ET PROCÉDÉS ASSOCIÉS

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(56) References cited:
EP-A1- 2 562 299
CN-A- 106 435 952
US-A- 2 387 320

Description

TECHNICAL FIELD

[0001] The present disclosure relates to hygro flat woven fabrics, articles, related processes for making same, and in particular to hygro flat woven fabrics and articles adapted for home textile uses, such as bedding.

BACKGROUND

[0002] Hygro materials can be used to describe materials, such as yarns and fabrics, which absorb water or moisture. Textile materials can absorb water through the fiber structure itself. For instance, cotton fibers are highly absorbent and textile materials that use cotton fibers can be absorbent materials. Textile materials can also be designed to absorb moisture through the specific yarn and woven fabric constructions. For example, lightly twisted yarn structure may absorb more moisture than highly twisted yarn structures. In another example, terry fabrics can typically absorb more moisture than flat fabrics due to the presence of piles and increased surface area available to absorb and transport moisture. It is challenging to balance the ability of a fabric structure to absorb moisture while also maintaining fabric durability and softness. This effort is further challenged by developing yarn structures that can readily withstand the rigors of weaving or other textile processes.

[0003] CN 106 435 952 discloses a flame retardant fabric and a preparation method thereof. PVA or soluble polyester (PET) filaments and Aramid fibers, flame-retardant viscose, polyester, modacrylic, or cotton fibers are spun into yarn and the yarn is woven or knitted to form a flame retardant sheet. PVA fibers are dissolved in hot water after fabric formation. PET filaments are dissolved using an alkaline after fabric formation.

[0004] US 2 387 320 discloses a highly stretchable yarn that is formed by wrapping a stretchable cotton or viscose yarn on a soluble cellulose yarn. The yarn may be woven or knitted into a fabric. The core fiber can be broken or destroyed using acetone in advance of the yarn being woven or knitted into a fabric.

[0005] EP 2 562 299 discloses a bulked yarn comprising a bulked single spun yarn obtainable from a composite twisted yarn in which a single spun yarn and a water-soluble yarn together in a direction opposite to the twisting direction of the single spun yarn by dissolving and removing the water-soluble yarn in a hydrophilic solvent from the composite twisted yarn is prepared. When the bulked yarn with a length of 100 cm is hung down in a state where both ends of the yarn are fixed at a distance of 10 cm from each other in a direction perpendicular to the direction of gravitational force, twisting does not occur or an average value of the distances from the uppermost end of a twisting section to the first and second fixed ends of the yarn is 30 cm or more. The bulked yarn has excellent texture, lightweight properties, and anti-pilling properties, as well as excellent weaving and knitting properties and productivity. Further, a woven or knit fabric comprising the bulked yarn is more lightweight, more voluminous, softer with an excellent touch, and better in heat-insulating properties and air permeability, has greater anti-pilling properties, sheds no fluff, and has better rapid-drying properties despite having great water absorbency.

SUMMARY

[0006] One aspect of the present invention provides a flat woven fabric that include multi-core staple yarns. The flat woven fabric includes a warp component including warp yarns, and a weft component including weft yarns interwoven with the warp yarns to define the woven fabric. At least one of a) the warp component and b) the weft component includes a plurality of multi-core staple yarns. Each multi-core staple yarn has a length, and comprises a sheath of dyed twisted together. A first hollow core and a second hollow core extends through the outer sheath of staple fibers along the length of the multi-core yarn. The cross-sectional dimension of each hollow core along the length of the multi-core yarn is between about 4% to about 20% cross-sectional dimension of the yarn and the total cross-sectional dimensions of the first and second hollow cores along the length of the multi-core yarn is between 8% and about 40% cross sectional dimension of the yarn. The first hollow core and the second hollow core may be twisted around and with respect to each other as each extends along the length. The woven fabric may be a bedding article that includes the woven fabric with multi-core staple yarns such as a flat sheet, a fitted sheet, a pillow case, a comforter, and a pillow sham.

[0007] Another aspect of the present invention provides process for manufacturing a woven fabric that includes multi-core staple yarns. The process includes spinning staple yarns to form a sheath of staple fibers twisted around a first core of water soluble fibers and a second core of water soluble fibers. The process further includes weaving the yarns into a flat woven fabric and dying and removing the first and second cores of water soluble fibers from a multi-core staple yarn having the first and second hollow cores. The weaving step may include weaving warp yarns and weft yarns with each other to define the flat woven fabric such that at least one of a) the warp yarns, and b) the weft yarns include the multi-core staple yarns. The weaving step may occur after the removing step. Alternatively, the weaving step may occur before the removing step..

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The foregoing summary, as well as the following detailed description of illustrative embodiments of the present application, will be better understood when read in conjunction with the appended drawings, which are described below. For the purposes of illustrating the present application, there is shown in the drawings illustrative embodiments of the disclosure. It should be understood, however, that the application is not limited to the precise arrangements and instrumentalities shown.

Figure 1A is a schematic view of a woven fabric formed with hygro yarns in accordance with an embodiment of the present invention.

Figure 1B is a cross-sectional view of the woven fabric taken along line 1B-1B in Figure 1A.

Figure 2 is a sectional side view of a terry fabric woven including hygro yarns in accordance with an embodiment of the present invention.

Figure 3A is a schematic side view of the multi-core hygro yarn used in fabrics illustrated in Figures 1A-2B;

Figure 3B is cross-sectional view of the multi-core yarn, taken along line 3B-3B in Figure 3A, and illustrating the first and second water soluble fiber core.

Figure 4A is a schematic side view of the multi-core hygro yarn illustrated in Figure 3A, after the first and water soluble fiber cores have been removed.

Figure 4B is cross-sectional view of the multi-core yarn, taken along line 4B-4B in Figure 4A, and illustrating the first and second water soluble fiber core.

Figure 5 a process flow diagram for manufacturing the multi-core hygro yarn and related fabrics, according to an embodiment of the present invention.

Figure 6 a process flow diagram for manufacturing textile articles with the multi-core hygro yarns, according to an embodiment of the present invention.

Figure 7 is schematic of an apparatus using in yarn spinning according to an embodiment of the present invention.

Figures 8A and 8B illustrate data related heat loss for certain flat woven fabrics.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0009] Disclosed herein are unique "hygro" textile structures, such as yarns, fabrics, and related articles that are highly absorbent, hydrophilic, soft, and adapted for home textile applications. The hygro textile structures may be suitable for bedding articles, such as sheeting products. Also described herein are processes and devices used to manufacture hygro textile structures. The hygro textile structures as described herein are formed with yarn configurations that include an outer sheath of fibers that surround inner, multiple, hollow cores. The multiple hollow cores are formed by the removal of soluble fibers, e.g. water soluble fibers, during the manufacturing process, as will be further explained below.

[0010] Yarn configurations in accordance with the claimed invention are single end yarns formed to include multiple cores of soluble fibers, as shown Figures 3A and 3B. After the soluble fibers are removed, the resulting structure is a single end, multi-core yarn 180 that includes multiple hollow cores, as shown Figures 4A and 4B. The process used to form the yarn multi-core yarn 180 illustrated in Figures 3A-4B will also be described in further below. The yarn structures that include soluble fibers as illustrated Figures 3A and 3B are referred to in the present disclosure as "intermediate yarns." The yarn structures where the soluble fibers have been removed as illustrated in Figures 4A and 4B are referred to in the present disclosure as "hygro yarns."

[0011] The resulting hygro yarn configurations as described herein in many circumstances boost manufacturing efficiency and improve end-product quality. For instance, multi-core yarns 180 shown in Figures 4A and 4B, the process used to form the yarns 180 results in increased productivity, which in turn, increases overall efficiency along the yarn-to-textile article supply chain. Embodiments of the present inention thus improve upon existing technologies used to form hygro yarns that include an outer sheath of cotton fibers and a single hollow core, such as those described in U.S. Patent No. 8,733,075, entitled, "Hygro Materials For Use In Making Yarns And Fabrics," (the "075 patent").

[0012] Embodiments of the present invention also include flat woven fabric 10 formed using the hygro yarns as described herein. An exemplary flat woven fabric 10 is shown in Figures 1A and 1B. The flat woven fabric 6 may be formed of multi-core staple hygro yarns 180 (see Figures 4A, 4B).

[0013] Referring to Figures 1A and 1B, the flat woven fabric 10 includes a warp component having warp yarns 20, and a weft component including weft yarns 40 that are interwoven with the warp yarns 20 to define the woven fabric. The warp yarns 20 extends along a warp direction 4 and the weft yarns 40 extend along a weft or fill direction 6 that is perpendicular to the warp direction 4. The woven fabric 10 includes a face 12, and back 14 opposite the face 12 along a thickness direction 8 that is perpendicular to the warp direction 4 and the weft direction 6. As illustrated, either or both of the warp component and the weft component may include the various hygro yarn configurations described herein. , Either or both of the warp component and the weft component may include the multi-core yarns 180 as describe herein. The flat woven fabrics 10 as described herein are suitable for bedding applications, such as sheeting fabrics. Accordingly, the flat woven fabric 10 can be converted into a sheeting article.

[0014] The woven fabric 10 as described herein may be defined by a number of different woven structures or woven design repeats. As used herein, a woven design repeat includes at least a first warp yarn 20a, a second warp yarn 20b, and at least one weft yarn 40. For example, a plain weave fabric has a woven design repeat that includes two adjacent warp yarns 20 and two adjacent weft yarns 40. Depending on the particular design, woven design repeats may repeat along: a) the weft direction 4; b) the warp direction 6; or both the weft direction 4 and warp directions 6. However, the design of the woven fabric 10 is not limited to a plain weave. For example, the woven fabric can have a number of exemplary woven structures including, but are not limited to: plain weaves; basket weaves, rib weaves (e.g. 2x1 rib weave; 2x2 rib weave; or 3x1 rib weave) twill weaves; oxford weaves; percale weaves, satin weaves (e.g. satin dobby base, satin stripe satin 5/1, satin 4/1 satin; 4/1 satin base strip; 4/1 stain swiss dot; 4/1 down jacquard;5/1 satins), or sateen weaves. In one example, the woven fabric is a plain weave. In another example, the woven fabric is a basket weave. In another example, the woven fabric is a rib weave. In another example, the woven fabric is a twill. In another example, the woven fabric is an oxford weave. In another example, the woven fabric is a satin weave. Furthermore, a number of exemplary satin constructions are possible. For instance, in one satin weave example, the woven fabric is a 4/1 satin. In another example, the woven fabric is a 4/1 satin dobby diamond weave. In another example, the woven fabric is a 4/1 satin dobby stripe. In yet another example, the woven fabric is a 4/1 satin jacquard weave. In another example, the woven fabric is a 5/1 satin. In still another example, the woven fabric may be a 6/1 satin. In another example, the woven fabric is a 7/1 satin. In yet another example, the woven fabric is a 8/1 satin. In another example, the woven fabric is a 9/1 satin. And in another example, the woven fabric is a 10/1 satin.

[0015] The claimed invention can utilize co-insertion techniques to insert multiple weft yarns 40 along a weft insertion path 19 in a single weft insertion event during weaving, as will be further detailed below. The weft insertion path 19 of weft yarn 40 is shown in dashed lines in Figures 1B. As used herein, the weft insertion path 19 extends along the weft direction 4 around the warp yarns 20 across an entirety of the width of the woven fabric 10. As illustrated, the weft insertion path extends under (with respect to the sheet) warp 20a, over warp yarn 20b, under warp yarn 20c, and over warp yarn 20d. A person of skill in the art will appreciate that the weft insertion path 19 varies from one woven design to another woven design. By inserting groups of multiple weft yarns into the shed during a weft insertion event, it is possible to attain increased weft (or pick or fill) densities and therefore higher thread counts. Thus, the woven fabric 10 as described herein may be constructed to have higher weft yarn densities than what is otherwise possible, and thus higher thread counts, yet the woven fabric 10 exhibits desirable fabric quality, softness, hand, and drape suitable for bedding applications. The thread count of the woven fabrics made in accordance with present invention is typically greater than about 15.5 per square centimeter (100 per square inch) and can be as high as about 155.5 per square centimeter (1000 per square inch) (or even higher). The thread count in this context is based on total number of yarn ends. In other words, plied yarns are considered one yarn for the purpose of determining thread count.

[0016] The claimed invention can utilize co-insertion techniques to insert multiple weft yarn 40 along a weft insertion path 19 in a single weft insertion event during weaving, as will be further detailed below. A "co-insertion" technique is where multiple pick or weft yarns are inserted into the warp shed at one time during weaving. In co-insertion, two pick yarns supplied from two different yarn packages are inserted at one time through the shed during weaving. Co-insertion may also include inserting three or more yarns supplied from the three or more different yarn packages into the shed during weaving. In one example, the woven fabric 10 has between one (1) weft yarn and seven (7) weft yarns inserted during a single insertion event, i.e. along the weft insertion path 19.

[0017] The warp yarns and weft yarns are arranged to achieve desired warp and weft end densities, respectively, and thus desired thread count, for bedding applications. In accordance with an embodiment of the present invention, the woven fabric has a warp end density between about 19.7 warp ends per centimeter (50 warp ends per inch) and about 137.8 warp ends per centimeter (350 warp ends per inch). In one example, the warp end density is between about 19.7 and 59 warp ends per centimeter (50 and 150 warp ends per inch). In another example, the warp end density is between about 59 and 98.4 warp ends per centimeter (150 and 250 warp ends per inch). In another example, the warp end density is between about 98.4 and 137.8 warp ends per centimeter (250 and 350 warp ends per inch). Furthermore, the weft yarns are arranged to define a weft end density between about 19.7 weft yarns per centimeter (50 weft yarns per inch) and about 275.6 weft yarns (700 weft yarns per inch) (or more). In one example, the weft yarn density is between about 39.4 and 275.6 weft yarns per centimeter (between about 100 and about 700 weft yarns per inch). In one example, the weft yarn density is between about 39.4 and 118.1 weft yarns per centimeter (between about 100 and 300 weft yarns per inch). In another example, the weft yarn density is between about 118.1 and 196.9 weft yarns per centimeter (between about 300 and 500 weft yarns per inch). In another example, the weft yarn density is between about 196.9 and 275.6 weft yarns per centimeter (between about 500 and about 700 weft yarns per inch). The weft yarn density has used herein refers to the total number of separate weft yarns along a length of the woven fabric. For example, a weft yarn density of about 50 picks per centimeter refers the 50 total weft yarns per centimeter of woven fabric. If the weft yarn groups are inserted during a single weft insertion event and each group includes three (3) weft yarns, then there would be about 16 total weft yarn groups per centimeter of fabric and 48 picks per centimeter.

[0018] The yarns can have a range of counts for the different fibers and woven constructions as described herein. The yarn count as used in this paragraph refers to the yarn count for each single end in the yarn count of the multi-core yarn 180. The yarn count can range between about 73.95 Tex (8 Ne (664 denier)) to about 4.92 Tex (120 Ne (44.3 denier)). In one example, the yarns can have a count in a range between about 73.95Tex (8 Ne (664 denier)). In one example, the yarns can have a count in a range between about 29.5 Tex (20 Ne (266 denier)). In one example, the yarns can have a count in a range between about 19.67 Tex (30 Ne (177 denier)). In one example, the yarns can have count in a range between about 14.75 Tex (40 Ne (133 denier)). In another example, the yarns have a count of about 9.83 Tex (60 Ne (88.6 denier)). In another example, the yarns have a count of about 8.43 Tex (70 Ne (75.9 denier)). In another example, the yarns have a count of about 7.38 Tex (80 Ne (66.4 denier)). In another example, the yarns have a count of about 5.9 Tex (100 Ne (53.1 denier)). In another example, the yarns have a count of about 4.92 Tex(120 Ne (44.3 denier)). For flat woven fabrics, the warp yarn counts may range from 29.5 Tex (20 Ne (266 denier)) to about 5.9 Tex (100 Ne (53.1 denier)). The weft yarn counts may range from 29.5 Tex (20 Ne (266 denier) to about 4.92 Tex (120 Ne (44.3.1 denier)(.

[0019] The flat woven fabric 10 can use different yarn constructions in the warp and weft components. In one example, the warp yarns are typical staple spun yarns (cotton or any fiber blends) and the weft yarns include multi-core hygro yarns 180. In one example, the warp yarns are typical continuous filament yarns and the weft yarns are multi-core hygro yarns 180. In another example, the weft yarns are typical staple spun yarns and the warp yarns are multi-core hygro yarns 180. In one example, the weft yarns are typical continuous filament yarns and the warp yarns are a multi-core hygro yarns 180. In one preferred embodiment, the warp yarns are typical staple spun yarns and the weft yarns include multi-core hygro yarns 180.

[0020] In accordance with an alternative embodiment of the present invention, the hygro yarns can be used to form other types of woven fabrics, for example, a terry fabric 110 as shown in Figure 2. As can be seen in Figure 2, in accordance with an alternative embodiment, a terry woven fabric 110 is illustrated that includes a ground component 130 that includes warp yarns 120 and weft yarns 140 interwoven with the warp yarns 120. The terry woven fabric 110 also includes one or more pile components 150a, 150b. The ground component 130 includes a first side 32 and a second side 34 opposite the first side. The pile component 150a and 150b extend away from opposite sides 32 and 34 of the ground component 130 along a thickness direction 8. The warp yarns 120 extend along a warp direction 4, which is perpendicular to the weft direction 6 and the thickness direction 9. The weft yarns 140 extend along a weft or fill direction 6 that is perpendicular to the warp direction 4. The woven fabric 110 includes a face 12, and back 14 opposite the face 12 along a thickness direction 8 that is perpendicular to the warp direction 4 and the weft direction 6. The terminal ends of the pile components 150a and 150b can define the face 12 and back 14 of the woven fabric 110. The piles have a pile height H that extends from the ground component to the terminal ends of the piles.

[0021] As illustrated in Figure 2, the terry woven fabric 110 includes a first pile component 150a and a second pile component 150b. However, the terry fabric may include only the one pile component. Each pile component 150a, 150b includes a plurality of piles 152a, 152b that project in a direction away from the ground component 130. The piles 152a, 152b are defined by pile yarns 154a, 154b interwoven with the ground component 130. The terry woven fabric 110 can be formed using any of the hygro yarn configurations described in the present disclosure. In one example, the pile yarns 154a, 154b may include the multi-core yarns 180. In such an example, one or both of the warp yarns 120 and the weft yarns 140 may include the multi-core yarns 180. The terry woven fabrics 110 may be converted bath and/or kitchen products, such as towel articles. Terry articles include a towel, a hand towel, a wash cloth, a bath robe, a rug, a kitchen towel, and the like.

[0022] Figures 3A-7 illustrate an intermediate multi-core yarn 160, multi-core hygro yarn 180, a processes 300 used form textile articles with the hygro yarns 180, and an apparatus 400 used during process 300 to form the hygro yarn 180. The yarn structures during and after removal of the water soluble fibers according to process 300 are illustrated in Figures 3A-4B. Figures 3A and 3B illustrates an intermediate yarn 160 with two yarns with pair of water soluble fiber cores 166aa and 166b. Figures 4A and 4B illustrates the resulting the hygro yarn 180 after the water soluble fibers have been removed resulting in a pair of hollow cores 184A, 184B surround by the outer sheath 184 of staple fibers. As illustrated, the hygro yarn 180 is a single ply two-ply yarn that includes a first hollow core 184A and a second hollow core 184B twisted with the first hollow core 184A about a yarn central axis A to define a multi-core hygro yarn 180.

[0023] As can be seen in Figures 3A-4B, the intermediate yarn 160 is formed to include an outer sheath of fibers 184 and an inner core 166a, 166a of water soluble fibers 168. The outer sheath 184 of fibers may be cotton fibers, similar to the embodiment described above and illustrated In Figures 3A-3B. Accordingly, the outer sheath of fibers 180 may include, in place of cotton, viscose fibers, modal fibers, silk fibers, modal fibers, acrylic fibers, polyethylene terephthalate (PET) fibers, polyamide fibers, are fibers blends. Fiber blends may, for example, include: blends of cotton and bamboo; blends of cotton and sea weed fibers; blends of cotton and silver fibers; blends of cotton and charcoal fibers; blends of PET fibers and cotton; blends of PET and viscose; blends of cotton and modal; blends of cotton; silk and modal; and any combinations thereof. The sheath may be 100% cotton or a combination of any of the foregoing blends.

[0024] The soluble fibers may be water soluble fibers. In one example, the soluble fibers are polyvinyl alcohol (PVA) fibers. The present embodiment, however, is not limited to PVA fibers unless the claims recite PVA fibers. The amount of soluble fibers present in the intermediate yarn 160 can vary from about 5% to about 40% of the weight of the yarn 160. The balance of the weight is comprised of the outer sheath of staple fibers. In one example, the soluble fibers may vary from about 10% to about 30 % of the weight of the yarn. In one example, the soluble fibers may vary from about 15% to about 25 % of the weight of the yarn. In one example, the soluble fibers may vary from about 17% to about 23 % of the weight of the yarn. In one example, the soluble fibers may be about 20 % of the weight of the yarn. However, it should be appreciated that the amount of soluble fibers can be any specific amount between 5% to about 40%.

[0025] The intermediate yarns 160 are processed to remove the water soluble fibers after fabric formation, which is similar to the process as described in the 075 patent. In alternative embodiments, however, the intermediate yarns 160 can be died prior to fabric formation to remove the water soluble fiber core 166a, 66b of water soluble fibers and apply color to the fibers in the outer sheath 184. After removal of the first and second water soluble fiber cores 166a and 166b, each yarn has an outer sheath 184 of staple fibers twisted around a first and second hollow core 188a and 188b to define the multi-core yarn 180 as illustrated in Figures 4A and 4B. As discussed above, by dissolving the PVA fibers, hollow air spaces are formed throughout the yarns, corresponding to an increase in the air space in the yarns. By increasing the air space in the yarn, the textile articles formed therefrom are softer and bulkier than textile articles made without the hygro yarns as described herein.

[0026] Turning to Figures 3A and 3B, removal of the water soluble fibers from the intermediate yarn 160 results in a multi-core yarn 180 having a plurality hollow cores 188a, 188b. The multi-core yarn 180 extends along a length L that is aligned with a yarn central axis A. As illustrated the multi-core yarn 180 includes a first hollow core 188a and a second hollow core 188b. The first and second hollow cores 188a and 188b twist about each other along the length L. Furthermore, the first and second hollow cores 188a and 188b twist about the central yarn axis A as they extend along the length L.

[0027] The first and second hollow cores 188a and 188b comprise a predefined portion of the yarn 180. The predefined portion may be described in terms of a percentage of yarn cross-sectional dimension (e.g. distance) and/or percentage of a volume of the yarn 180. For instance, the multi-core yarn 180 defines a yarn cross-sectional dimension D1 that is perpendicular to the yarn central axis A. The first hollow core 188a can define a first core cross-sectional dimension F1. The second hollow core 188b can define a second cross-sectional dimension F2. The yarn cross-sectional dimension D1, the first cross-sectional dimension F1, the second cross-sectional dimension F2 are aligned along the same direction G. As discussed above, the phrase "cross-sectional dimension" is the longest distance across a point of reference in the yarn structure. The cross-sectional dimension may be measured using image analysis techniques, as noted above. In accordance with the illustrated embodiment, each hollow core defines between about 4 % to about 20 % of the yarn cross-sectional dimension D1. For instance, the combined extent of the first core cross-sectional dimension F1 and the second core cross-sectional dimension F2 is between about 8% to about 40 % of the yarn cross-sectional dimension D1 of the multi-core yarn 180. In other words, F1 plus F2 is between about 8% to about 40 % of the yarn cross-sectional dimension D1 of the multi-core yarn 180. In one example, the first and second hollow cores 188a and 188b together define between about 10% to about 30 % of the cross-sectional dimension D1. In another example, the first and second hollow cores 188a and 188b together define between about 15% to about 25 % of the yarn cross-sectional dimension D1. The percentages described above correspond to the approximate weight percentage of water soluble fibers in the intermediate yarn 160 before their removal from the yarn.

[0028] Similarly, the first and second hollow cores 188a, 188b comprise a defined volume percentage of the multi-core yarn 180. As described above, the volume percentage is determined assuming that the multi-core yarn 180 is cylindrical. The yarn volume V1 is equal to $[\pi(D1/2)^2]*h$, where D1 is the yarn cross-sectional dimension D1 defined above and h is a given length L of the yarn 180. The first hollow core volume V2 is equal to $[\pi(F1/2)^2]*h$, where F1 is the cross-sectional dimension F1 of the first hollow core 188a. The second hollow core volume V3 is equal to $[\pi(F2/2)^2]*h$, where F2 is the cross-sectional dimension F2 of the second hollow core 188a. The volume percentage of the hollow core is equal to $[(V2+V3)/V1]*100$. In accordance with the illustrated embodiment, the first and second hollow cores 188a and188b comprises between about 8% to about 40% of the volume of the multi-core yarn 180. In one example, the first and second hollow cores 188a and188b define between about 10% to about 30% of the volume of the multi-core yarn 180. In another example, the first and second hollow cores 188a and188b defines between about 15% to about 25% of the volume of the multi-core yarn 180. The volume percentage of the first and second hollow cores 188a, 188b also correspond to the approximate weight percentage of water soluble fibers in the intermediate yarn 160 before remove of the water soluble fibers.

[0029] The multi-core yarn 180 can be twisted to have ether a z-twist or a s-twist. Furthermore, the multi-core yarn 180 can be plied into a plied yarn structure. Each yarn in the multi-core yarn in such a plied structure can have a twist direction that is opposite to the twist direction of the multi-core yarn. For instance, if the plied multi-core yarn has a Z-twist, each multi-core yarn 180 end will have an s-twist and vice versa.

[0030] Forming the multi-core yarn 180 illustrated in Figures 4A-4B into textile articles will be described next. Figures 5 and 6 illustrate a method 300 for manufacturing hygro textile articles with the multi-core yarns 180. Figure 7 illustrates an apparatus 400 used during spinning to help form the multi-core yarn 180. The method 300 described below refers to use of cotton fiber in the outer sheath and of PVA fibers used to form the inner fiber cores 166a and 166b. However, it should be appreciated that other fibers can be used in the outer sheath and the inner cores, as described above.

[0031] The method 300 illustrated includes two preliminary phases: outer sheath sliver formation 302 and soluble fiber sliver formation 304. Outer sheath sliver formation 302 creates slivers used to form the outer sheath of fibers 184 in the intermediate yarn 160 while soluble fiber sliver formation 304 creates slivers used to form the inner cores 166a and 166b of soluble fibers in the intermediate yarn 160.

[0032] Outer sheath fiber formation phase 302 forms slivers of staple fibers for roving. Outer fiber sliver formation initiates with fiber receiving 306 and storage 308. The outer sheath fiber formation phase 302 is similar to the outer sheath formation phase 202 illustrated in Figure 5. For instance, the outer sheath fibers (or cotton fibers) are subject to an opening step 310 in a blow room. In the blow room, the cotton fibers are processed with a bale plucker, opener, multi-mixer, beater and a dustex machine. After opening 310, the fibers are carded 312 on card machines to deliver card slivers. The sliver from carding is then processed through a breaker drawing step 314 to draw out the slivers. In case of blended slivers, each component is separately processed through carding and the individual carded slivers are subsequently blended together on draw frames. After breaker drawing 314, the slivers can be fed to the speeding frame 332 or inter a lapping step 316 and combing step 318.

[0033] For combed yarns, the draw frame slivers are processed via lapping 216. In lapping, a unilap machine convers doublings into a lap of fibers. The lap is processed in a combing step 318 using a comber. The combed cotton sliver is then passed through another drawing step 320 using a finisher draw frame. The output of the finisher draw frame is fed into the speed frame to make roving for later yarn spinning.

[0034] Soluble fiber sliver formation will be described next. Soluble fiber sliver formation phase 304 is substantially similar the soluble fiber formation phase 204 described above and illustrated in Figure 5. Accordingly, similar soluble fiber configurations, e.g. cut length, denier, etc., as described with respect to the sliver formation phase 204 shown in Figure 5 are used during the soluble fiber formation phase 304. The soluble fiber formation phase 304 includes a receiving step 322, and a storage step 324. Next, the soluble fibers are subject to an opening step 226 in a blow room in a "cotton" type spinning system. After opening 326, the PVA fibers are conveyed from the blow room to carding 328 to form card slivers, which are coiled into sliver cans. The carded slivers are then further drawn via drawing step 330 to yield the PVA sliver. During the drawing step 330, the carded slivers are passed through one or more draw frames to further orient the fibers. For instance, during drawing 330, the PVA slivers are initially processed with a breaker draw frame and a second pass of drawing uses a finisher draw frame. The output of the drawing 330 are cans of PVA slivers that fed into the roving step 332.

[0035] After outer fiber sliver formation 302 and soluble fiber sliver formation 304, the staple fibers (or outer fibers) and soluble fiber slivers are combined during roving 332. Roving 332 is substantially similar to the roving 232 illustrated in Figure 5 and described above. For example, during roving 332, the soluble fiber sliver is inserted into a middle or central portion of the cotton sliver at a speed frame to yield a single roving 140 (Fig. 11) with a water soluble fiber core. As described above, the speed frame used in the roving step 332 includes an inlet condenser, a middle condenser, a main feed condenser, multiple sets of drafting rollers, and a flyer. The cotton sliver follows a normal path from the back to the front of the speed frame through at least the main feed condenser. The inlet and middle condensers are incorporated for feeding PVA slivers at the inlet, the back and middle drafting zones on the speed frame, to ensure that the PVA sliver stays in the middle of the cotton sliver. The PVA sliver, however, passes through the inlet condenser before occupying the middle portion on the cotton sliver in the main feed condenser, similar to roving step 232 described above. Alternative mechanisms for feeding PVA fiber roving into the path of the cotton roving in the drafting zone of a speed frame can be used as well. In one embodiment, the PVA fibers can be added via core-spinning machine. In another variation, the PVA roving is introduced in the path of cotton roving on the roving machine. Alternatively, the PVA can be added to the middle of the cotton roving by reversing the rotation of flyer in the counter-clock-wise direction, which is opposite the direction of the normal flyer rotation. In both situations, the PVA fibers are placed in the middle of the cotton sliver during the roving process to yield a roving with a core of PVA fibers.

[0036] Continuing with Figures 5 and 7, a multi-core spinning step 334 converts two rovings 140 and 142 into an intermediate multi-core yarn 160 using an apparatus 400 of a spinning frame. Turning to Figure 11, the apparatus 400 includes a roving guide 404, rear rollers 408, and pre-drafting zone condensers that exit side of the rear rollers 408. The apparatus includes a middle roller and apron assembly 416, main drafting zone condense 420, and front rollers 424, and a yarn guide 430. In operation, the roving ends 140 and 142 are fed separately through the drafting zones and converge at the yarn guide 430. Between rollers 428 and yarn guide 430, the ends 140 and 142 are twisted about each other into a single end yarn structure, or intermediate yarn 160. The intermediate yarns 160 exit the rollers 428 and are wound into suitable bobbins. In step 334, subsequent spinning following exit from the apparatus 400 is accomplished using typical settings for forming ring spun yarns. The spinning parameters, however, on the ring frame are set based on the type of fibers in the outer sheath and type and content of the PVA fibers in the inner cores 166a and 166b. Because the input of the apparatus 400 are two ends 140 and 142 each having a water soluble fiber core, the intermediate yarn 160 exiting will be wound onto the bobbins as a single yarn 160 having first water soluble fiber core 166a and a second water soluble fibers core 166b, as illustrated in Figure 3A and 3B.

[0037] The spinning step 334 can produce single end yarns 160 with a count that ranges from about 73.75 Tex (8 Ne) to about 4.92 Tex (120 Ne). Yarns used for a flat woven fabric 10 (Figures 1A & 1B) may have a count that ranges from 29.5 Tex (20 Ne) to about 4.92 Tex (120 N)e. Yarns used for terry fabrics 110 (Figure 2) may have a count that ranges from about 73.75 Tex (8 Ne) to about 11.8 Tex (50 Ne). After yarn spinning 334, the intermediate multi-core yarn 160 can be further packaged 340 into a suitable yarn packages. Alternative, the intermediate multi-core yarn 160 can be plied into a plied yarn configuration as needed.

[0038] Turning to Figure 10, the next phase in the production of hygro textile articles is fabric formation, soluble fiber removal and dyeing, followed by article formation. The multi-core yarn packages formed during packaging 340 are received 342 and stored 344 for warping 348. The warping step 348 includes typical warping operations for flat woven fabrics 10. In alternative embodiment for terry production, the warping operations includes steps typical for terry fabrics 110: ground yarn warping and pile yarn warping. After warping 348, a sizing step 349 can be used to applying sizing composition to the warp ends.

[0039] A weaving step 350 follows sizing 349 and warping 348. The weaving step 350 converts the yarns into woven fabrics. The weaving step 350 converts the yarns into woven fabrics. One or more looms, e.g. air-jet looms, rapier looms, water-jet looms (or others) can be use during the weaving step. Each loom may utilize typical shedding mechanism, such as a dobby or jacquard type shedding mechanism. During the weaving step for the woven fabric 10 (Figure 1A, 1B), the warp and weft yarns can be arranged into a number of different weaving constructions and designs as is known by persons of skill in the art and that detailed above. For instance, the flat woven fabrics may include a plain weave, twills, rib weaves, basket weaves, percale, satins, sateens, other woven designs. In accordance with an embodiment of the present invention, the weaving step forms a woven fabric to have a) a warp end density between about 19.7 warp ends per centimeter (about 50 warp ends per inch) and about 137.8 warp ends per centimeter (about 350 warp ends per inch); and b) a weft end density between about 19.7 weft yarns per centimeter (about 50 weft yarns per inch) and about 275.6 weft yarns per centimeter (about 700 weft yarns per inch) (or more). In one example, the weft yarn density is between about 39.4 and 275.6 weft yarns per centimeter (between about 100 and about 700 weft yarns per inch). Furthermore, the flat woven fabrics may have thread counts ranging from 15.5 per square centimeter (100 per square inch) to about 155 per square centimeter (1000 per square inch). The weaving step may include co-insertion or insertion of multiple picks during a single pick insertion event. In one example, the weaving step includes inserting between one (1) weft yarn and seven (7) weft yarns during a single insertion event along the weft insertion path 19 (Fig. 1A). Furthermore, for woven fabrics 10, the weft yarns, warp yarns, or both the warp and weft yarns can include the multi-core hygro yarns 180. The flat woven fabrics are formed to have constructions that are suitable for bedding applications in both consumer, hospitality and /or healthcare markets.

[0040] In alternative embodiments, during the weaving step for terry fabrics 110, the ground, weft, and pile yarns are woven together using a loom configured for terry production. The terry fabric 110 can be 3-pick, 4-pick, 5-pick, 6-pick, or 7-pick terry. In the one example, the terry fabric 110 is a 3-pick terry. The pile component 150a, 150b can define a pile height H that extends from the ground component 130 to a top of a pile154, 154b along the thickness direction 8. The pile height can range from about 2.0 to 10 mm.

[0041] The weaving step 350 results in "greige fabrics" that are further processed into textile articles. After the weaving step 350, the griege fabrics are inspected 352. Following inspection 352, the fabrics can either undergo a batch dyeing and soluble fiber dissolving step 346a or a continuous dyeing and fiber dissolving step 356a.

[0042] The batch dyeing and soluble fiber dissolving step 346a includes scouring, bleaching, and dyeing dyed in a typical fashion in a fabric dyeing machine. The operating temperature is maintained in a range from about 95 degrees Celsius to about 120 degrees Celsius. In one example, the temperature is about 120 degrees Celsius, which can help ensure that all the PVA fibers are dissolved in the water. The batch dyeing step 346a utilizes a liquor ratio sufficient to facilitate prompt dissolution of the PVA fibers, while allowing free movement of the fabric in the dyeing machine. The liquor ratio may range from about 1:5 to about 1:30. For example, the liquor ratio may be 1:10, 1: 12, 1:15, 1:20, 1:25, 1:22, or 1:28.

[0043] During step 346a, the fabrics are typically wound into the shape of a rope prior to entering the fabric-dyeing machine. The rotation of the fabric in rope form aids in promoting rapid dissolution of the PVA fibers. The dissolution step 346a also includes washing and rinsing the fabric. After washing, the liquor is drained and fresh water is injected into the machine for rinsing the fabric and to remove all the dissolved PVA from the fabric and machine. During the washing and rinse phase, the water is at a temperature ranging from about 55 degrees Celsius to about 100 degrees Celsius Preferably, the water is at a high temperature, such as 100 degrees Celsius. The fabric can be rinsed in hot water after draining to wash away any PVA residue. After unloading the woven fabrics from the vessel, the water is extracted material in an extractor in the typical manner to reduce the moisture content. Next, an opening step 256 untwists the fabric using a rope opener, similar to the rope opener as described in the 075 patent. Following the rope opening step, a drying step 358 dries the fabric further.

[0044] As described above, after the inspection step 352, the griege fabric can processed using continuous dyeing range in a continuous dyeing step 346b using similar process temperatures as used in the batch step 346a. After the continuous dyeing step 346b, the woven fabric is dried 358. The drying step 358 utilizes a hot air dryer to further dry the fabrics at the desired temperature. The dried fabric is expanded to full width and then passed through a stentering step 360. The stentering step 360 can help straighten the fabric.

[0045] In certain alternative embodiments for processing terry fabrics, a shearing step is used, whereby both sides of the terry fabric are passed through a shearing machine. The shearing machine has cutting devices, such as blades and/or a laser, which are set such that only protruding fibers are cut and the piles are not cut. The shearing step reduced linting during subsequent washing in use by the consumer.

[0046] The result of process 300 is a textile article formed from a woven fabric, such as a flat woven fabric 10 or terry fabric 110, which include multi-core hygro yarns 180, as illustrated in Figures 4A and 4B.

[0047] Following the stentering step 360 (or optional shearing step), a cutting step 362 cuts the woven fabrics to the desired length and width depending on the particular end use. Steps 372, 374 and 376 may be used to form textile articles based on a flat woven fabric 10. For flat woven fabrics 10, after cutting 362, the cut woven fabric is stitched 372, inspected 376, and a packaged 376. Packaging step 376 may include folding and packing the textile articles into packages or containers for shipment. Alternatively, after the cutting step 362, processing steps 366, 368, 376 and 378 may be used to form textile articles with terry fabrics 110. For terry fabrics 110, after the cutting step 362, the cut terry fabrics length hemmed 366, cross-cut 368, cross-hemmed 378, inspected 376, and the packaged 376. A carton package step 378 follows to prepare the packages for transport to customers.

[0048] The flat woven fabric 10 formed as described including the multi-core hygro yarn 180 has better comfort profiles comparted to typical flat woven fabrics. The comfort profile may be related to the flat woven fabrics ability to absorb moisture in combination with the desirable heat and moisture transfer properties. The comfort profile as described herein related to the ability of the flat woven fabric to keep a user cool in warmer environmental conditions and warm in cooler environmental conditions. While not being bound to any particular theory, it is believed that flat woven fabrics as described herein that include multi-core hygro yarn 180 are more comfortable to the user compared to sheeting products made with typical yarn constructions.

[0049] The comfort profile in this context relates to heat transfer and moisture properties of the flat woven fabrics. The heat and moisture transfer properties can be determined in accordance with ASTM F 1868, *Standard Test Method for Thermal and Evaporative Resistance of Clothing Materials Using a Sweating Hot Plate,* Part C. This test is referred to herein as the "*Thermal and Evaporative Resistance*" test). Two exemplary flat woven fabrics were constructed and included the attributes illustrated in Table 1.

Table 1 Example Flat Woven Fabrics for Thermal and Evaporative Resistance Test

Example	A	B
Fiber Content	100% Cotton	100% Hygro Cotton
Thread Count	62 per square cm (400 per square inch)	62 per square cm (400 per square inch)
Warp Tex	7.38 (80 Ne)	7.38(80 Ne)
Weft Tex	7.38 (80 Ne)	7.38 (80 Ne)
Ends per cm	77.2 (196 EPI)	77.2 (196 EPI)
Pricks per cm	79.1 (201 PPI)	791. (201PPI)
Weave Design	Satin	Satin
Weight(g/m^2)	122.4 (3.61oz/yd^2)	135.52(3.997oz/yd^2)
Thickness (mm)	0.23	0.23

[0050] The "Thermal and Evaporative Resistance" test is a measure of heat flow from the calibrated test plate (heated to a skin surface temperature of 35 degrees Celsius) through the flat woven fabric into the test environment (25 degrees Celsius, 65%RH). Heat flow is determined for both simulated dry and wet skin conditions. Heat loss parameters can be calculated from the following thermal transport measurements.

[0051] The total thermal resistance (Ret), [(Δ°C)(m^2)/W], is the total resistance to dry heat transfer (insulation) for a fabric including the surface air layer. Total thermal resistance (Rct) is given by the following equation:

$$Rct = [(TS - Ta) \cdot A]/[H],$$

where Ts is the temperature of the plate surface (35°C), Ta is the temperature in the local environment (25°C), A is the area of the test plate (0.01 m^2), and W is the power input (W).

[0052] The intrinsic thermal resistance (Rcf), [(Δ°C)(m^2)/W], is the resistance to dry heat transfer provided by the fabric alone. Intrinsic thermal resistance (Rcf), is determined by subtracting the average dry bare plate resistance (Rcbp) from the average of the total thermal resistance (Rct) of the specimens.

[0053] The bare plate thermal resistance (Rcbp), [(Δ°C)(m^2)/W], is the resistance to dry heat provided by the surface air layer as measured on the bare plate. Bare plate thermal resistance values are shown in table 3 below.

[0054] The apparent total evaporative resistance (RetA), [(ΔkPa)(m^2)/W], is the total resistance to evaporative heat transfer for a fabric including the surface air layer and liquid barrier (the descriptor term 'apparent' is added to account for the fact that heat transfer may have an added condensation component in nonisothermal conditions). Apparent total evaporative resistance (RetA) is given by the following equation:

$$RetA = [(Ps - Pa) \cdot A/H - (Ts - Ta) \cdot A]/Rct,$$

where Ps is the water vapor pressure at the surface plate (kPa), Pa is the water vapor pressure in the local environment (kPa), A is the area of the test plate (0.01 m^2), H is power input (W), Ts is temperature at the plate surface (35°C), Ta is temperature at the local environment (25°C), and Rct is the total thermal resistance as defined above.

[0055] The apparent intrinsic evaporative resistance (RefA), [([[(ΔkPa)(m^2)/W], is the resistance to evaporative heat transfer provided by the fabric alone. The apparent intrinsic evaporative resistance (RefA), is determined by the apparent total evaporative resistance (RetA) minus the average bare plate evaporative resistance (Rebp).

[0056] The bare plate thermal resistance (Rebp), [(ΔkPa)(m^2)/W], is the resistance to evaporative heat transfer provided by the liquid barrier and surface air layer as measured on the bare plate (with liquid barrier attached).

[0057] Total heat loss (Qt), [W/m^2],is an indicator of the heat transferred through the fabric material by the combined dry and evaporative heat loss, from a fully sweating test plate surface into the test environment. Total heat loss, measured at a 100% wet skin condition, indicates the highest predicted metabolic activity level that a user may sustain and still maintain body thermal comfort while in a highly stressed state in a test environment. Total heat loss (Qt) is calculated using the following equation:

$$Q_t = \frac{10°C}{R_{cf} + .04} + \frac{3.57\ kPa}{R_{et}^{A} + .0035}$$

[0058] The total insulation value (It), [clo], is the thermal resistance measured in units of clo, which indicates the insulating ability of the fabric material. Materials with higher clo values provide more thermal insulation. The clo value includes the insulation provided by the air layer above the fabric and does not subtract it out as with Rcf discussed above. It (clo) values are derived using dry plate test results, from the formula It = Rct*6.45.

[0059] The im value, or permeability index, indicates moisture-heat permeability through the fabric on a scale of 0 (totally impermeable) to 1 (totally permeable) normalized for the permeability of still air (naked skin). This comfort parameter indicates the effect of skin moisture on heat loss as in the case of a sweating skin condition. This value includes the evaporative resistance provided by the air layer above the sample and does not subtract it out as with RefA discussed above. The Im value (permeability index) is calculated, using both dry and sweating plate test results,from the formula Im = 0.060 * (Rct/RetA).

[0060] The average values for Rct, RetA, Rcf, RefA, It, im, and Qt of the Examples A and B are shown in Table 2 below. The average bare plate values are shown in Table 3. Weights and thicknesses for each sample are given in Table 1 above.

Table 2 Sweating Hot Plate Data

Example	Ret	RetA	Rcf	RefA	It	Im	Qt
A	0.08 0	0.0084 9	0.012	0.0032 7	0.51 8	0.568	720.1 2
B	0.08 0	0.0073 7	0.012	0.0021 4	0.51 8	0.655	825.0 6

Table 3 Bare Plate Test Data

	Rcbp	Rebp
Average	0.068	0.005220

Heat transfer makes it possible to predict the body heat that will flow from the skin surface through the flat woven fabric into the surrounding atmosphere. As illustrated in table 2 above, example B, which included the hygro yarn configuration, had greater heat loss in humid and sweat conditions and increased ability to transport moistures, e.g. sweat. Table 3 indicates that Evaporative Resistance(RetA) for example A is greater than the Evaporative Resistance(RetA) for example A, indicating that example B allows moisture transfer more quickly to the atmosphere. The total heat loss (Qt) for example B is higher than the total heat loss for example A, indicating example B can transfer heat more quickly to the atmosphere, which indicates the example B fabrics would keep a user more cool.

[0061] The comfort profile also relates thermal insulation properties of flat woven fabrics used to form sheeting products. The thermal insulation properties can be determined in terms of thermal resistance and can be measured accordance with ASTM F 1291 *Standard Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin.* Exemplary flat woven fabrics were constructed and included the attributes illustrated in Table 4.

Table 4 Examples for Thermal and Evaporative Resistance Test

Example	C	D	E
Fiber Content	100 % Cotton	100% Hygro Cotton	100% Hygro Cotton
Thread Count	62 per square cm (400 per square inch)	62 per square cm (400 per square inch)	62 per square cm (400 per square inch)
Warp Tex	7.38 (80 Ne)	7.38 (80 Ne)	7.38 (80 Ne)
Weft Tex	7.38 (80 Ne)	8.43 (70 Ne)	9.83 (60 Ne)
Ends per cm	77.2 (196 EPI)	77.2 (196 EPI)	77.2 (196 EPI)
Picks per cm	79.1 (201 PPI)	79.1 (201 PPI)	79.1 (201 PPI)
Weave Design	Satin	Satin	Satin

Tests for thermal resistance should occur in non-isothermal conditions, such as those shown in Table 5. Prior to testing the manikin was stabilized in the 20°C environment within the chamber. After the bed was made, the test session was started and the manikin was placed on the mattress/fitted sheet and was covered with the accompanying top-sheet. After which the manikin was left to stabilize for 20 minutes. After the 20 minute mark the conditions of the chamber would be changed from 20°C to 25°C. Once 25°C was reached the manikin was allowed to stabilize at which point the test session was stopped. One repetition was completed for each sheet set, as specified by the above referenced test standard.

Table 5 Testing Conditions

	Thermal Resistance
Air Temperature (°C)	20-25
RH (%) ~60	

(continued)

	Thermal Resistance
Air Speed (m/s)	0.2-0.4
Skin Temperature (°C)	35

Thermal resistance measurements were taken from all sections (Whole Body) as well as the front of manikin (the area completely covered by the test sheets and not in contact with a mattress). Thermal resistance values were converted to units of clo. The measurement of heat transfer is a measure of heat flow from the manikin surface (heated to a skin surface temperature of 35°C) through an ensemble into the test environment and is determined for both simulated dry and wet skin conditions. Heat loss parameters in this context, calculated from thermal transport measurements, include;a) the total thermal resistance (Rct) provided by the manikin, fabric ensemble, and air layers; b) the total evaporative resistance *(Ret),* [kPa·m2/W], which is the total evaporative resistance provided by the manikin, fabric ensemble, and air layers; c) the intrinsic thermal resistance *(Rcl)*, [°C·m2/W], total thermal resistance provided by the garment ensemble only; d) the intrinsic evaporative resistance, [kPa·m2/W] is the intrinsic evaporative resistance provided by the fabric ensemble only; e) the total insulation value (It), [clo]; f) the Im value, or permeability index; and g) the predicted heat loss potential (Qt), [W/m2], is a predicted level of the total amount of heat that could be transferred from the manikin to the ambient environment for a specified condition. It uses the thermal and evaporative resistance values to calculate indicates that sheeting products made from examples D and E will tend to keep a user cooler compared to sheeting products made from example C. indicates that sheeting products made from examples D and E will tend to keep a user cooler compared to sheeting products made from example C.

Claims

1. A woven fabric (10), comprising:

a warp component including warp yarns (20); and
a weft component including weft yarns (40) interwoven with the warp yarns (20) to define the woven fabric (10), **characterized in that**:

at least one of a) the warp component (20), and b) the weft component (40) includes a plurality of multi-core yarns (180), each multi-core yarn (180) having a length and comprising a sheath of dyed staple fibers (184) twisted together,
wherein a first (188a) and a second (188b) hollow core extend through the sheath of staple fibers (184) along the length of the multi-core yarn (180), the cross-sectional dimension (F1, F2) of each hollow core (188a, 188b) along the length of the multi-core yarn (180) being between about 4% to about 20% cross-sectional dimension (D1) of the yarn (180) and the total cross-sectional dimensions of the first (188a) and second (188b) hollow cores along the length of the multi-core yarn (180) being between 8% and about 40% cross sectional dimension (D1) of the yarn (180).

2. The woven fabric of claim 1, wherein the first hollow core (188a) and the second hollow core (188b) are twisted around and with respect to each other as each extends along the length of the sheath of staple fibers (184).

3. The woven fabric of claim 1 or claim 2, wherein the plurality of multi-core staple yarns (180) has a first tensile strength adapted for formation into the woven fabric, and each dyed staple yarn has a second tensile strength that is less than the first tensile strength.

4. The woven fabric of any preceding claim, wherein the staple fibers are a) cotton fibers, or b) blends of cotton fibers with one or more other fibers.

5. The woven fabric of any preceding claim, wherein the warp (20) and weft yarns (40) are arranged to define a thread count between about 15.5 per square centimeter and about 155 per square centimeter (a thread count between about 100 and 1000).

6. The woven fabric of any preceding claim, wherein the warp end density is between about 19.7 warp ends per centimeter and about 137.8 warp ends per centimeter (between about 50 warp ends per inch and 350 warp ends per inch).

7. The woven fabric of any preceding claim, wherein the weft yarn density is between about 39.4 and about 275.6 weft yarns per centimeter (between about 100 and 700 weft yarns per inch).

8. The woven fabric of any preceding claim, wherein each dyed staple yarn has a fineness between about 4.92 and about 29.5 Tex (a count between about 20 Ne and 120 Ne).

9. A process (300) for manufacturing a flat woven fabric (10,110) in accordance with claim 1, the method comprising:

   spinning (334) staple yarns to form a sheath (184) of staple fibers twisted around a first inner core of water soluble fibers (166a) and a second inner core of water soluble fibers (166b);
   weaving (350) a plurality of the spun staple yarns (160) into a flat woven fabric (10,110); and
   dying (346a) the spun staple yarns (160) thereby removing the first (166a) and second (166b) inner cores of water soluble fibers from the spun yarns (160) to form dyed multi-core staple yarns (180) having first (188a) and second (188b) hollow cores, the cross-sectional dimension (F1, F2) of each hollow core (188a, 188b) along the length of the multi-core yarn (180) being between about 4% to about 20% cross-sectional dimension (D1) of the yarn (180) and the total cross-sectional dimensions of the first (188a) and second (188b) hollow cores along the length of the multi-core yarn (180) being between 8% and about 40% cross sectional dimension (D1) of the yarn (180).

10. The process of claim 9, wherein the weaving step (350) is weaving a flat woven fabric (10) having warp yarns (20) and weft yarns (40), wherein at least one of the warp yarns (20) and the weft yarns (40) comprises multi core staple yarns (180).

11. The process of claim 9 or 10, wherein the weft yarns (20) comprise multi core staple yarns (180).

12. The process of any of claims 9 to 11, wherein the weaving step (350) includes inserting one or more weft yarns (40) into warp yarns (20) during a single weft insertion event.

Patentansprüche

1. Gewebe (10), umfassend:

   eine Kettkomponente, die Kettgarne (20) beinhaltet; und
   eine Schusskomponente, die Schussgarne (40) beinhaltet, die mit den Kettgarnen (20) verwoben sind, um das Gewebe (10) zu definieren,
   dadurch gekennzeichnet, dass:

      mindestens eine von a) der Kettkomponente (20) und b) der Schusskomponente (40) eine Vielzahl von Mehrkerngarnen (180) beinhaltet, wobei jedes Mehrkerngarn (180) eine Länge aufweist und eine Hülle aus gefärbten Stapelfasern (184), die miteinander verzwirnt sind, umfasst,
      wobei sich ein erster (188a) und ein zweiter (188b) Hohlkern entlang der Länge des Mehrkerngarns (180) durch die Hülle aus Stapelfasern (184) erstrecken, wobei die Querschnittsabmessung (F1, F2) jedes Hohlkerns (188a, 188b) entlang der Länge des Mehrkerngarns (180) zwischen etwa 4% bis etwa 20% der Querschnittsabmessung (D1) des Garns (180) beträgt und die Gesamtquerschnittsabmessungen des ersten (188a) und zweiten (188b) Hohlkerns entlang der Länge des Mehrkerngarns (180) zwischen 8% und etwa 40% der Querschnittsabmessung (D1) des Garns (180) betragen.

2. Gewebe nach Anspruch 1, wobei der erste Hohlkern (188a) und der zweite Hohlkern (188b) umeinander und bezogen aufeinander verzwirnt sind, während sie sich jeweils entlang der Länge der Hülle aus Stapelfasern (184) erstrecken.

3. Gewebe nach Anspruch 1 oder Anspruch 2, wobei die Vielzahl von Mehrkernstapelgarnen (180) eine erste Zugfestigkeit aufweist, die für die Bildung des Gewebes angepasst ist, und jedes gefärbte Stapelgarn eine zweite Zugfestigkeit aufweist, die geringer ist als die erste Zugfestigkeit.

4. Gewebe nach einem der vorhergehenden Ansprüche, wobei es sich bei den Stapelfasern um a) Baumwollfasern oder b) Mischungen aus Baumwollfasern mit einer oder mehreren anderen Fasern handelt.

5. Gewebe nach einem der vorhergehenden Ansprüche, wobei die Kett- (20) und Schussgarne (40) so angeordnet sind, dass sie eine Fadenzahl zwischen etwa 15,5 pro Quadratzentimeter und etwa 155 pro Quadratzentimeter (eine Fadenzahl zwischen etwa 100 und 1000) definieren.

6. Gewebe nach einem der vorhergehenden Ansprüche, wobei die Kettfadendichte zwischen etwa 19,7 Kettfäden pro Zentimeter und etwa 137,8 Kettfäden pro Zentimeter (zwischen etwa 50 Kettfäden pro Zoll und 350 Kettfäden pro Zoll) liegt.

7. Gewebe nach einem der vorhergehenden Ansprüche, wobei die Schussgarndichte zwischen etwa 39,4 und etwa 275,6 Schussgarnen pro Zentimeter (zwischen etwa 100 und 700 Schussgarnen pro Zoll) liegt.

8. Gewebe nach einem der vorhergehenden Ansprüche, wobei jedes gefärbte Stapelgarn eine Feinheit zwischen etwa 4,92 und etwa 29,5 Tex (eine Zahl zwischen etwa 20 Ne und 120 Ne) aufweist.

9. Verfahren (300) zum Herstellen eines Flachgewebes (10,110) gemäß Anspruch 1, wobei das Verfahren Folgendes umfasst:

Spinnen (334) von Stapelgarnen, um eine Hülle (184) aus Stapelfasern zu bilden, die um einen ersten inneren Kern aus wasserlöslichen Fasern (166a) und einen zweiten inneren Kern aus wasserlöslichen Fasern (166b) verzwirnt sind;
Weben (350) einer Vielzahl der gesponnenen Stapelgarne (160) zu einem Flachgewebe (10,110); und
Färben (346a) der gesponnenen Stapelgarne (160), wodurch der erste (166a) und zweite (166b) innere Kern aus wasserlöslichen Fasern aus den gesponnenen Garnen (160) entfernt werden, um gefärbte Mehrkernstapelgarne (180) zu bilden, die einen ersten (188a) und einen zweiten (188b) Hohlkern aufweisen, wobei die Querschnittsabmessung (F1, F2) jedes Hohlkerns (188a, 188b) entlang der Länge des Mehrkerngarns (180) zwischen etwa 4% bis etwa 20% der Querschnittsabmessung (D1) des Garns (180) beträgt und die Gesamtquerschnittsabmessungen des ersten (188a) und zweite (188b) Hohlkerns entlang der Länge des Mehrkerngarns (180) zwischen 8% und etwa 40% der Querschnittsabmessung (D1) des Garns (180) betragen.

10. Verfahren nach Anspruch 9, wobei es sich bei dem Webschritt (350) um Weben eines Flachgewebes (10) handelt, das Kettgarne (20) und Schussgarne (40) aufweist, wobei mindestens eines der Kettgarne (20) und der Schussgarne (40) Mehrkernstapelgarne (180) umfasst.

11. Verfahren nach Anspruch 9 oder 10, wobei die Schussgarne (20) Mehrkernstapelgarne (180) umfassen.

12. Verfahren nach einem der Ansprüche 9 bis 11, wobei der Webschritt (350) Einführen eines oder mehrerer Schussgarne (40) in Kettgarne (20) während eines einzigen Schusseinführungsvorgangs beinhaltet.

Revendications

1. Tissu tissé (10), comprenant :

un composant de chaîne comprenant des fils de chaîne (20) ; et
un composant de trame comprenant des fils de trame (40) entrelacés avec les fils de chaîne (20) pour définir le tissu tissé (10),
caractérisé en ce que :

au moins l’un parmi a) le composant de chaîne (20) et b) le composant de trame (40) comprend une pluralité de fils multiâmes (180), chaque fil multiâme (180) comportant une longueur et comprenant une gaine de fibres discontinues teintes (184) torsadées ensemble,
dans lequel une première (188a) et une seconde (188b) âmes creuses s’étendent à travers la gaine de fibres discontinues (184) sur la longueur du fil multiâme (180), la dimension en section transversale (Fl, F2) de chaque âme creuse (188a, 188b) sur la longueur du fil multiâme (180) étant comprise entre environ 4 % et environ 20 % de la dimension en section transversale (D1) du fil (180) et les dimensions totales en

coupe transversale de la première (188a) et la seconde (188b) âmes creuses sur la longueur du fil multiâme (180) étant comprises entre 8 % et environ 40 % de la dimension en coupe transversale (D1) du fil (180).

2. Tissu tissé selon la revendication 1, dans lequel la première âme creuse (188a) et la seconde âme creuse (188b) sont torsadées autour et l'une par rapport à l'autre tandis que chacune s'étend sur la longueur de la gaine de fibres discontinues (184).

3. Tissu tissé selon la revendication 1 ou la revendication 2, dans lequel la pluralité de fils discontinus multiâmes (180) comportent une première résistance à la traction adaptée à la formation dans le tissu tissé, et chaque fil discontinu teint comporte une seconde résistance à la traction qui est inférieure à la première résistance à la traction.

4. Tissu tissé selon l'une quelconque des revendications précédentes, dans lequel les fibres discontinues sont a) des fibres de coton, ou b) des mélanges de fibres de coton avec une ou plusieurs autres fibres.

5. Tissu tissé selon l'une quelconque des revendications précédentes, dans lequel les fils de chaîne (20) et de trame (40) sont disposés pour définir un nombre de fils compris entre environ 15,5 par centimètre carré et environ 155 par centimètre carré (un nombre de fils compris entre environ 100 et 1 000).

6. Tissu tissé selon l'une quelconque des revendications précédentes, dans lequel la densité des extrémités de chaîne est comprise entre environ 19,7 extrémités de chaîne par centimètre et environ 137,8 extrémités de chaîne par centimètre (entre environ 50 extrémités de chaîne par pouce et 350 extrémités de chaîne par pouce).

7. Tissu tissé selon l'une quelconque des revendications précédentes, dans lequel la densité des fils de trame est comprise entre environ 39,4 et environ 275,6 fils de trame par centimètre (entre environ 100 et 700 fils de trame par pouce).

8. Tissu tissé selon l'une quelconque des revendications précédentes, dans lequel chaque fil discontinu teint comporte une finesse comprise entre environ 4,92 et environ 29,5 Tex (un nombre compris entre environ 20 Ne et 120 Ne).

9. Procédé (300) pour fabriquer un tissu tissé plat (10, 110) selon la revendication 1, le procédé comprenant :

le filage (334) de fils discontinus pour former une gaine (184) de fibres discontinues torsadées autour d'une première âme interne de fibres solubles dans l'eau (166a) et d'une seconde âme interne de fibres solubles dans l'eau (166b) ;
le tissage (350) d'une pluralité de fils discontinus filés (160) en un tissu tissé plat (10, 110) ; et
la teinte (346a) des fils discontinus filés (160), retirant ainsi les première (166a) et seconde (166b) âmes internes de fibres solubles dans l'eau des fils filés (160) pour former des fils discontinus multiâmes teints (180) comportant des première (188a) et seconde (188b) âmes creuses, la dimension en coupe transversale (F1, F2) de chaque âme creuse (188a, 188b) sur la longueur du fil multiâme (180) étant comprise entre environ 4 % et environ 20 % de la dimension en coupe transversale (D1) du fil (180) et les dimensions totales en coupe transversale des première (188a) et seconde (188b) âmes creuses sur la longueur du fil multiâme (180) étant comprises entre 8 % et environ 40 % de la dimension en coupe transversale (D1) du fil (180).

10. Procédé selon la revendication 9, dans lequel l'étape de tissage (350) consiste à tisser un tissu tissé plat (10) comportant des fils de chaîne (20) et des fils de trame (40), dans lequel au moins l'un des fils de chaîne (20) et des fils de trame (40) comprend des fils discontinus multiâmes (180).

11. Procédé selon la revendication 9 ou 10, dans lequel les fils de trame (20) comprennent des fils discontinus multiâmes (180).

12. Procédé selon l'une quelconque des revendications 9 à 11, dans lequel l'étape de tissage (350) comprend l'insertion d'un ou plusieurs fils de trame (40) dans des fils de chaîne (20) lors d'un même événement d'insertion de trame.

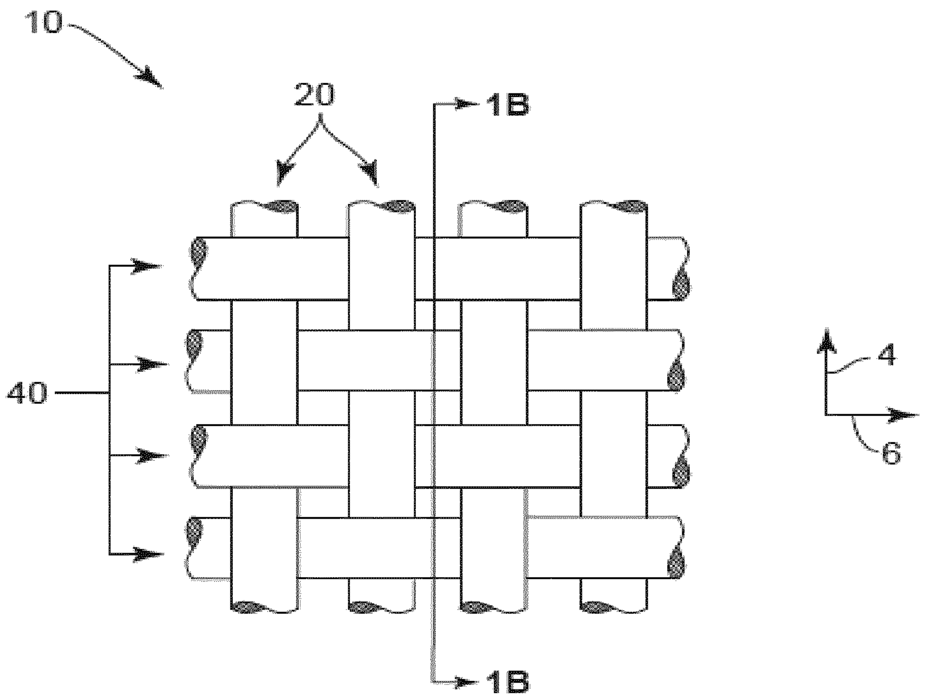


FIG. 1A

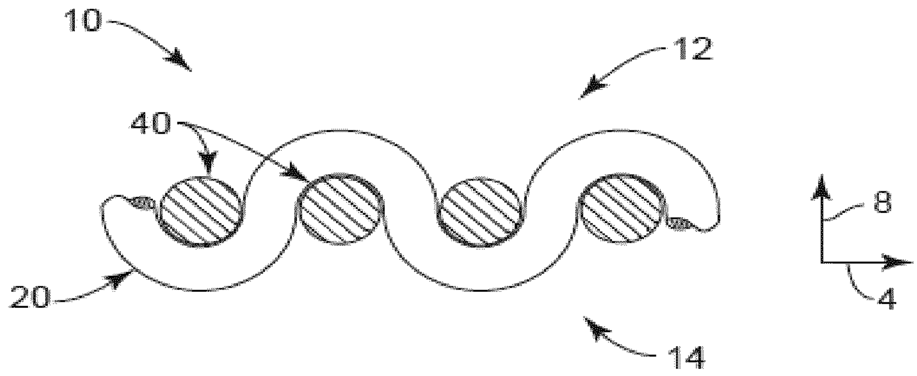


FIG. 1B

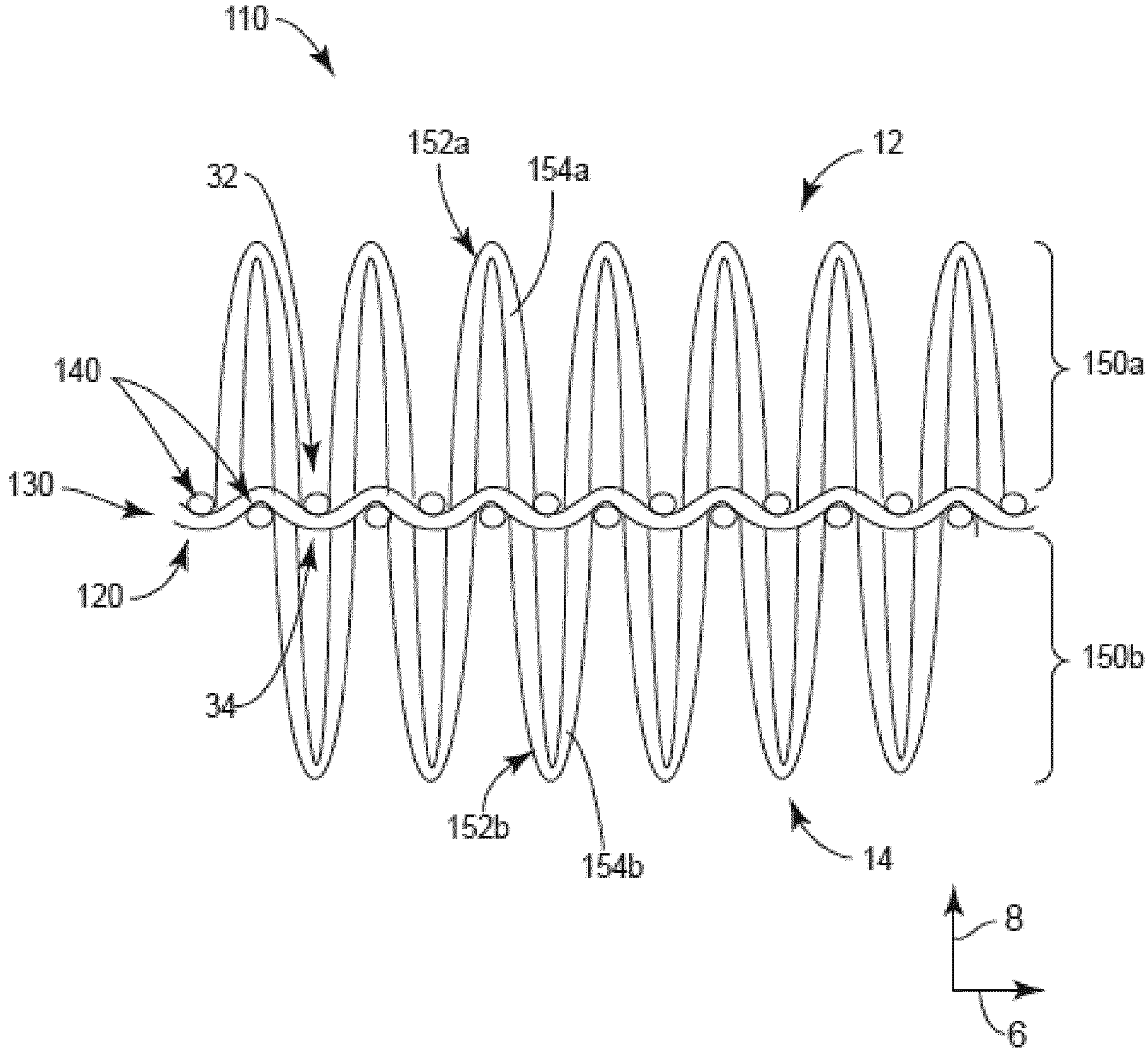


FIG. 2

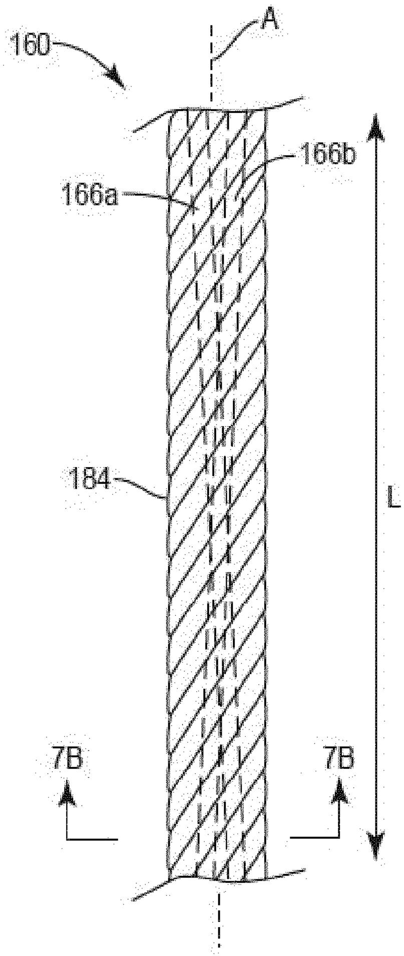


FIG. 3A

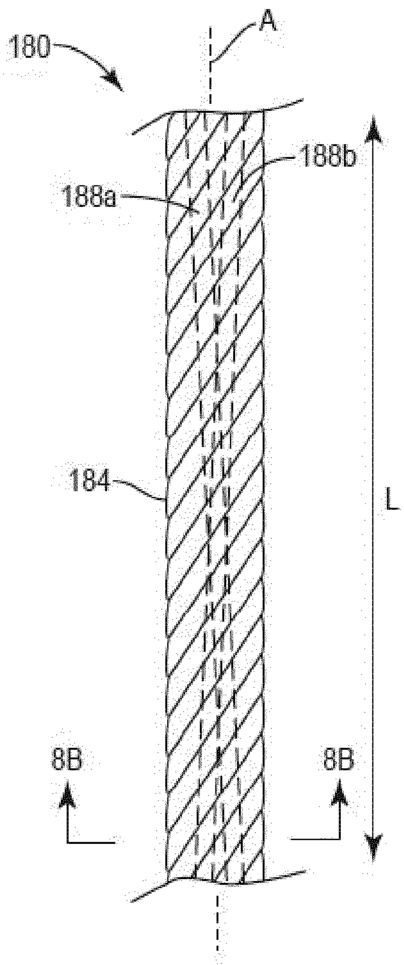


FIG. 4A

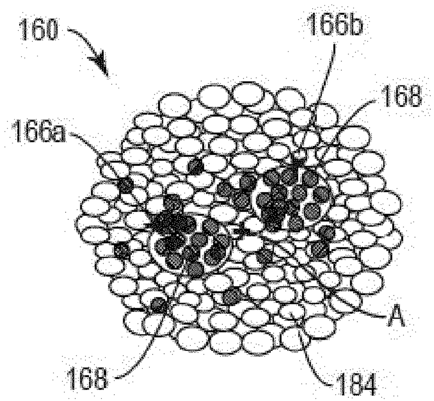


FIG. 3B

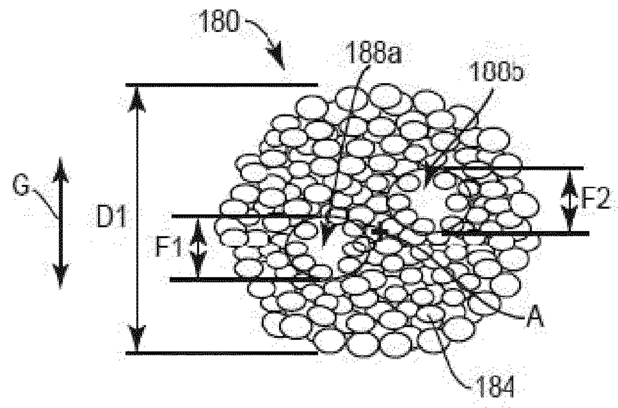


FIG. 4B

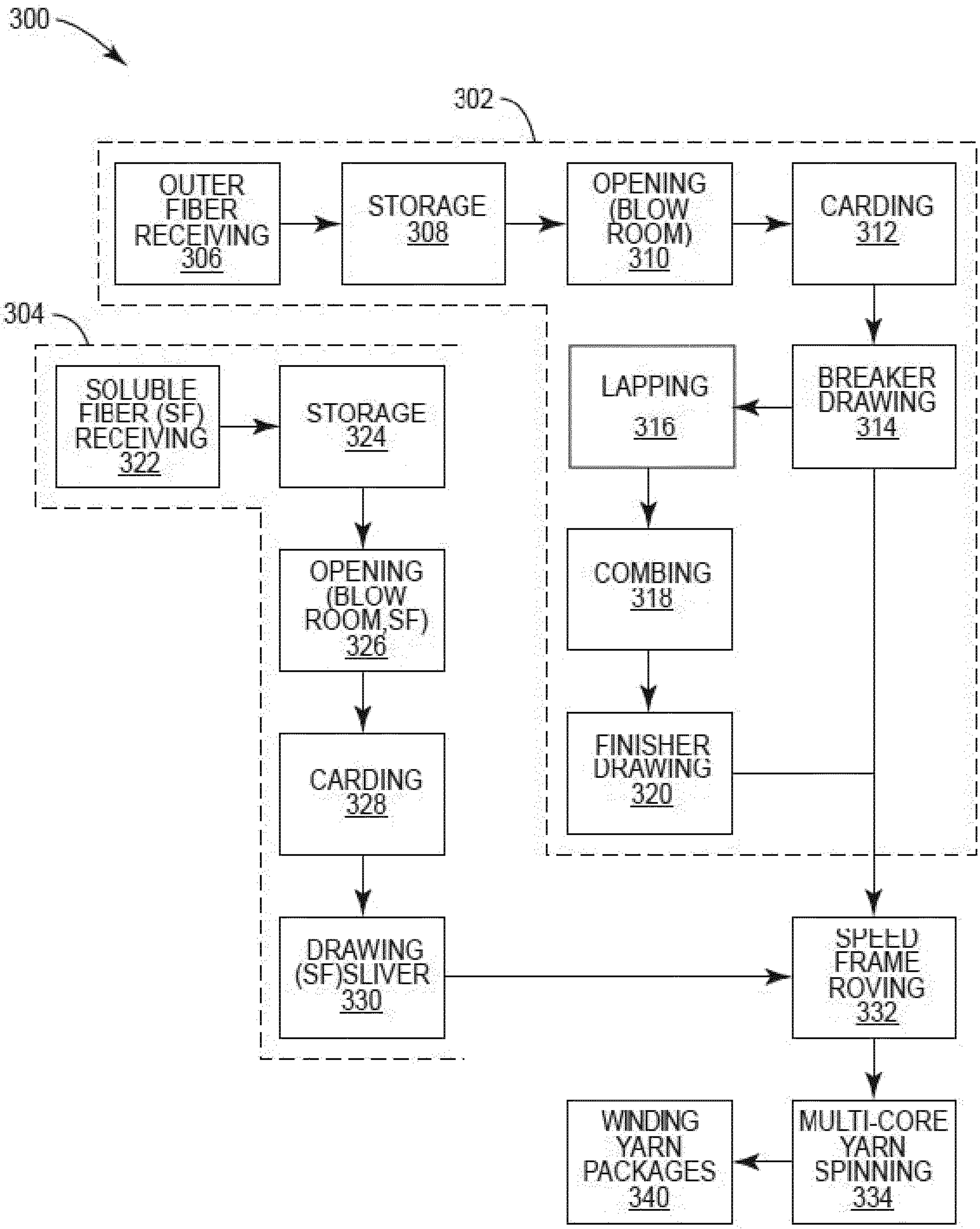
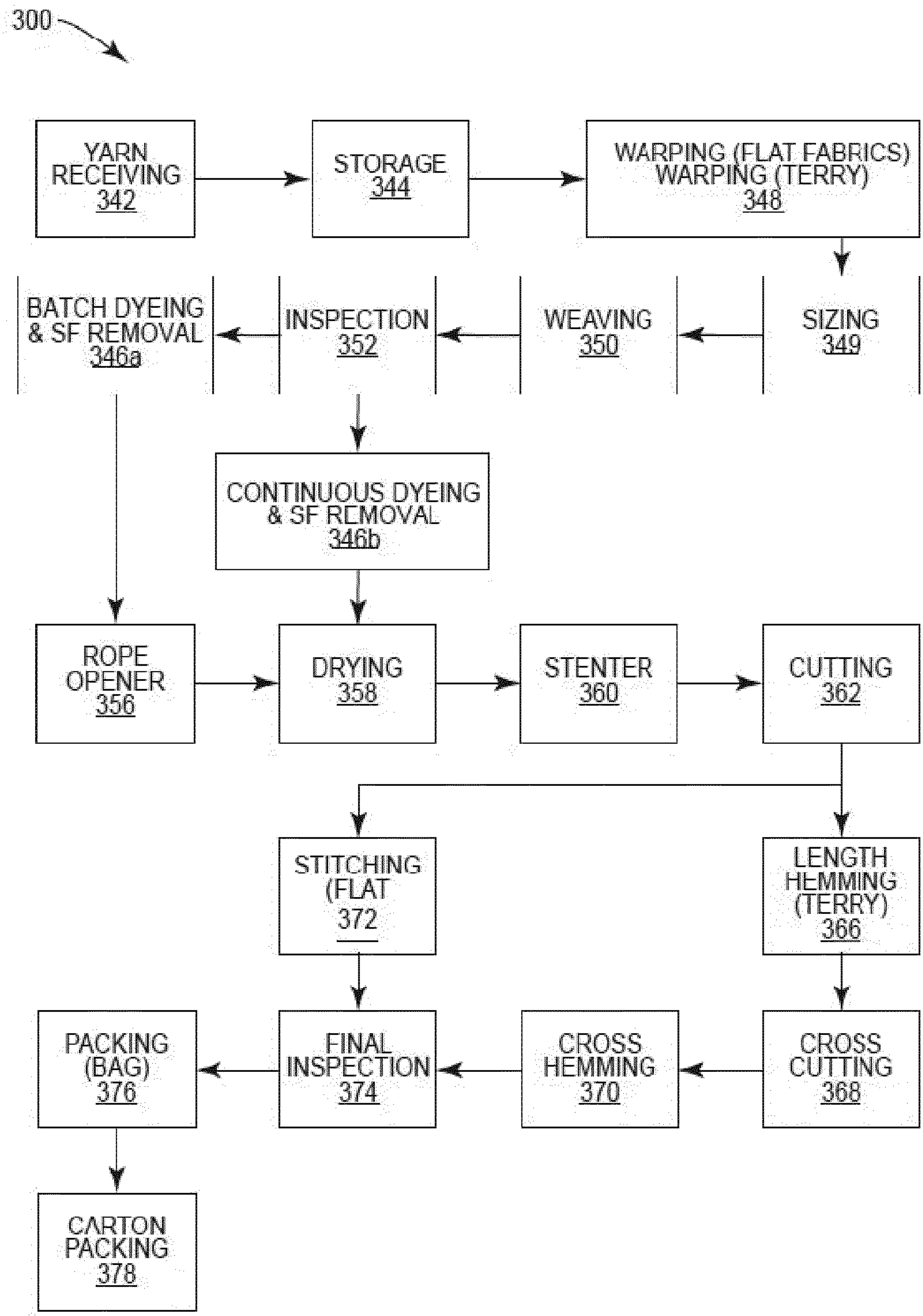

300
302
304
OUTER FIBER RECEIVING 306
STORAGE 308
OPENING (BLOW ROOM) 310
CARDING 312
SOLUBLE FIBER (SF) RECEIVING 322
STORAGE 324
LAPPING 316
BREAKER DRAWING 314
OPENING (BLOW ROOM,SF) 326
COMBING 318
CARDING 328
FINISHER DRAWING 320
DRAWING (SF)SLIVER 330
SPEED FRAME ROVING 332
WINDING YARN PACKAGES 340
MULTI-CORE YARN SPINNING 334

FIG. 5


300
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STORAGE 344
WARPING (FLAT FABRICS) WARPING (TERRY) 348
BATCH DYEING & SF REMOVAL 346a
INSPECTION 352
WEAVING 350
SIZING 349
CONTINUOUS DYEING & SF REMOVAL 346b
ROPE OPENER 356
DRYING 358
STENTER 360
CUTTING 362
STITCHING (FLAT 372
LENGTH HEMMING (TERRY) 366
PACKING (BAG) 376
FINAL INSPECTION 374
CROSS HEMMING 370
CROSS CUTTING 368
CARTON PACKING 378

FIG. 6

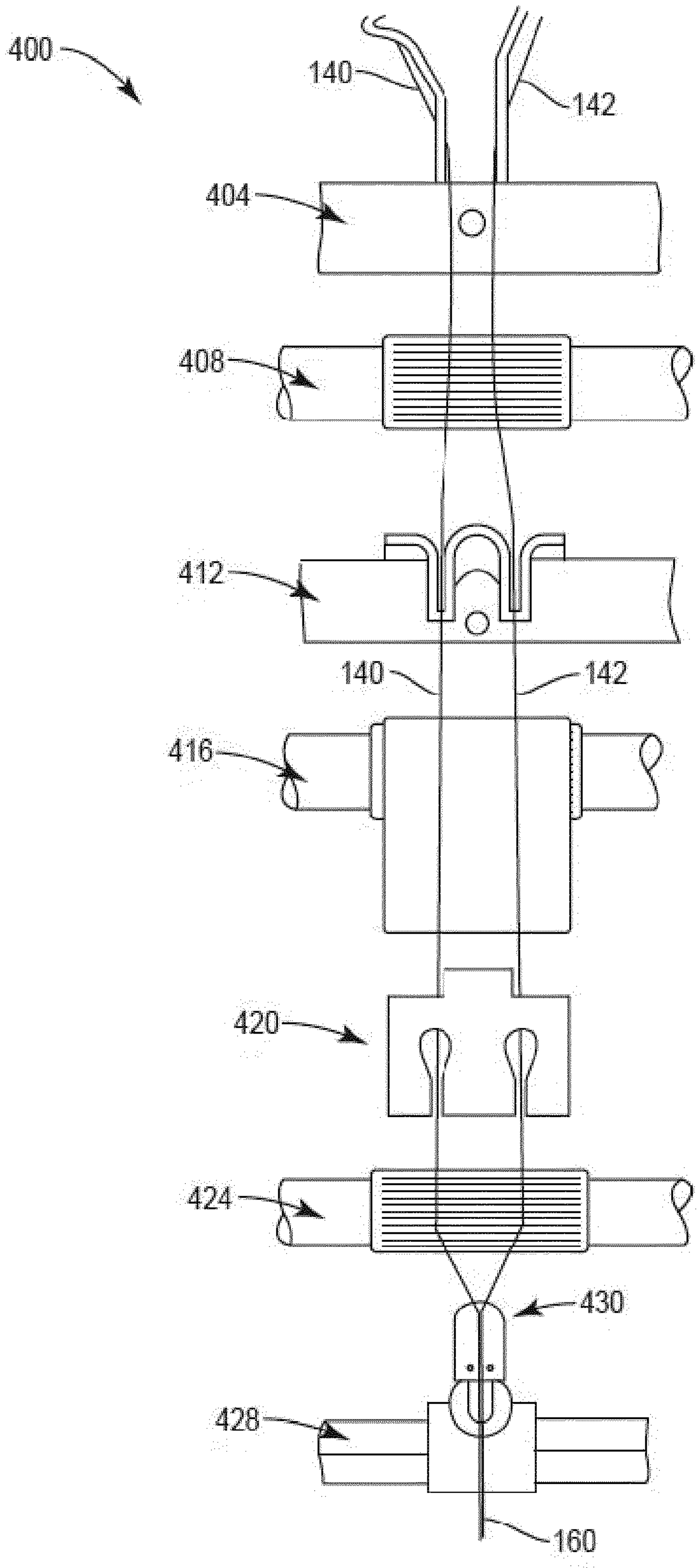
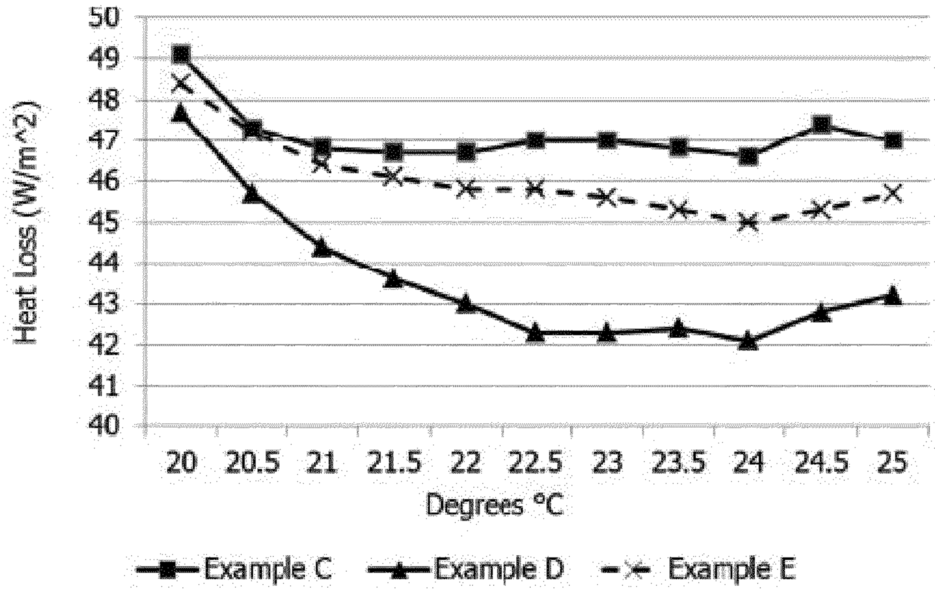


FIG. 7


50
49
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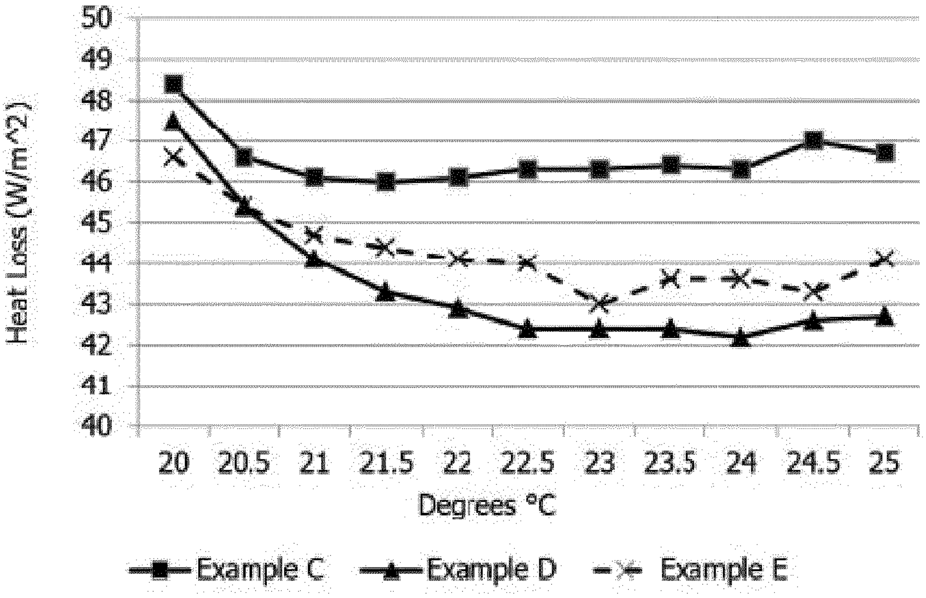
47
46
45
44
43
42
41
40
Heat Loss (W/m^2)
20
20.5
21
21.5
22
22.5
23
23.5
24
24.5
25
Degrees °C
Example C
Example D
Example E

FIG. 8A


50
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40
Heat Loss (W/m^2)
20
20.5
21
21.5
22
22.5
23
23.5
24
24.5
25
Degrees °C
Example C
Example D
Example E

FIG. 8B

REFERENCES CITED IN THE DESCRIPTION

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