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(71) Applicant: **Welspun India Limited**
Mumbai 400013 (IN)

(72) Inventors:
- **GOENKA, Dipali**
  400 013 Mumbai
  Maharashtra (IN)
- **PALIT, Subrata**
  400 13 Mumbai
  Maharashtra (IN)

(74) Representative: **Finnegan Europe LLP**
1 London Bridge
London SE1 9BG (GB)

Remarks:
The references to the drawing(s) no. 7A and 7B are deemed to be deleted (Rule 56(4) EPC).

(54) HYDROENTANGLED WOVEN FABRIC

(57) The present disclosure describes a hydroentangled woven fabric. The hydroentangled woven fabric (10) includes a plurality of warp yarns (20) and a plurality of weft yarns (40) interwoven with the plurality of warp yarns to define the hydroentangled woven fabric. The hydroentangled woven fabric has a first side (12) and a second side (14) opposite the first side. The hydroentangled fabric has a plurality of compact interstitial spaces between the plurality of warp yarns and the plurality of weft yarns. The plurality of warp yarns and the plurality of weft yarns are bulky around the compact interstitial spaces. The hydroentangled fabric has a compact thickness that extends in a direction from the first side of the hydroentangled woven fabric to the second side of the hydroentangled woven fabric. The compact thickness and bulky warp and weft yarns give rise to a compact and moisture wicking hydroentangled woven fabric.

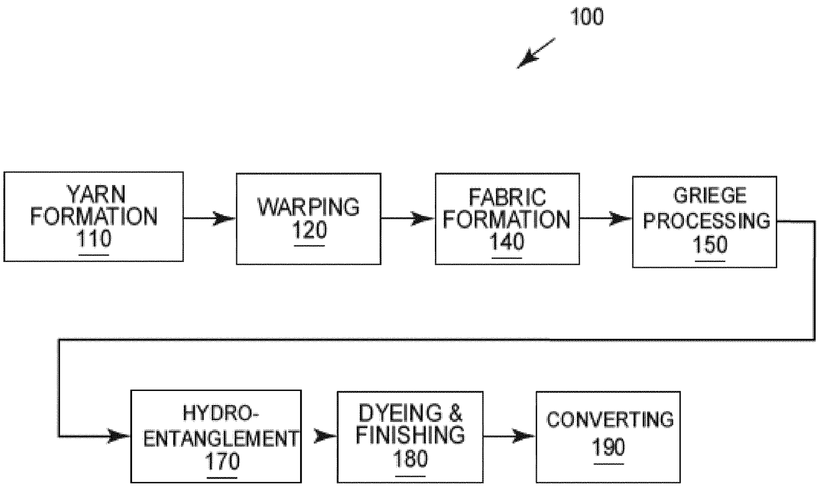

FIG. 3

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a hydroentangled woven fabric and a method of making such a hydroentangled woven fabric.

BACKGROUND

[0002] Woven fabrics made from cotton yarns or cotton blended yarns are widely used for bedding applications and garments due to the comfort properties these particular fabrics possess. Comfort in textile applications is a complex and is influenced by a number of fabric and yarn structural parameters, environmental use conditions, user preferences, and even user perceptions. From a structural standpoint, fibers and yarn structures that yield fabrics with soft, smooth hand-feel and drape well are typically considered high comfort fabrics. Moisture management properties in fabrics also play a role in comfort. For example, high wicking fabrics transport moisture quickly, which can translate in the ability to move sweat from the body to the surrounding atmosphere quickly. Fabric thermal properties also influence comfort. A fabric that retains heat may be suitable for use in cooler environments but may not be best suited for hot environments. Balancing fiber selection, yarn design, fabric design, and process parameters with desired end use properties is a difficult in application where "comfort" is an important decision point for consumers, such as bedding and garment applications. Typical structures used in bedding applications, such a cotton and cotton blended yarns, or cotton/polyester blended fabrics present challenges in achieving the right balance of strength, durability, softness, moisture management, and thermal resistance that is associated with comfortable materials.

SUMMARY OF INVENTION

[0003] There is need for woven fabrics with improved comfort related to softness, moisture management, thermal properties, and anti-allergen properties. An embodiment of the present disclosure is a hydroentangled woven fabric. The hydroentangled woven fabric includes a plurality of warp yarns and a plurality of weft yarns interwoven with the plurality of warp yarns to define the hydroentangled woven fabric. The hydroentangled woven fabric has a first side and a second side opposite the first side. The hydroentangled fabric has a plurality of compact interstitial spaces between the plurality of warp yarns and the plurality of weft yarns. The plurality of warp yarns and the plurality of weft yarns are bulky around the compact interstitial spaces. The hydroentangled fabric has a compact thickness that extends in a direction from the first side of the hydroentangled woven fabric to the second side of the hydroentangled woven fabric. The compact thickness and bulky warp and weft yarns give rise to a compact and moisture wicking hydroentangled woven fabric.

[0004] Another embodiment is a method for forming a hydroentangled woven fabric. The method includes weaving a plurality of warp yarns with a plurality of weft yarns to define a woven fabric having first interstitial spaces between the warp yarns and the weft yarns. The first interstitial spaces have a first dimension that is perpendicular to a thickness of the woven fabric. The method includes applying high-pressure water jets to the woven fabric to define the hydroentangled woven fabric having second interstitial spaces between the warp yarns and the weft yarns. The second interstitial spaces have a second dimension that is perpendicular to the thickness and that is smaller than the first dimension. The method may include drying the hydroentangled woven fabric to remove moisture from the hydroentangled woven fabric. The hydroentangled woven fabric defines a) a plurality of compact interstitial spaces, and b) a compact thickness that extends in a direction from a first side of the hydroentangled woven fabric to a second side of the hydroentangled woven fabric

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] 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. For purposes of illustrating the present application, the drawings show exemplary embodiments of the present disclosure. It should be understood, however, that the present disclosure is not limited to the precise arrangements and instrumentalities shown in the drawings. In the drawings:

Figure 1 is a schematic a hydroentangled woven fabric according to an embodiment of the present disclosure;

Figure 2 is a cross-sectional view of the hydroentangled woven fabric taken along line 2-2 in Figure 1;

Figure 3 is a schematic of a portion of a manufacturing system used to form the hydroentangled woven fabric illustrated in Figure 1;

Figure 4 is a process flow diagram for a method of making a hydroentangled woven fabric illustrated in Figures 1 and 2;

Figure 5A is an image showing the woven fabric before hydroentangling according to an embodiment of the present disclosure;

Figure 5B is an image showing the woven fabric shown in Figure 5A after hydroentangling;

Figure 6A is an image showing the woven fabric before hydroentangling according to another embodiment of the present disclosure;

Figure 6B is an image showing the woven fabric shown in Figure 6A after hydroentangling;

Figure 7A is an image showing the woven fabric before hydroentangling according to another embodiment of the present disclosure; and

Figure 7B is an image showing the woven fabric shown in Figure 7A after hydroentangling.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0006] Referring to Figures 1-2, embodiments of the present disclosure include a hydroentangled woven fabric 10. The hydroentangled 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. The face 12 may be referred to as the first side of the woven fabric and the back 14 may be referred to as the second side of the woven fabric 10. The hydroentangled woven fabric 10 has a compact thickness T that extends along a thickness direction 8 from the first side 12 of the hydroentangled woven fabric 10 to the second side 14 of the hydroentangled woven fabric 10. The hydroentangled woven fabrics 10 as described herein are suitable for bedding applications, such as sheets, fitted sheets, pillow cases, shams, duvets, blankets, comforters, pillow cases, mattress covers, and/or mattress pads.

[0007] Referring to Figure 1, the hydroentangled woven fabric 10 has a plurality of compact interstitial spaces 60 between the plurality of warp yarns 20 and the plurality of weft yarns 40. The woven fabric 10 also defines interstitial dimensions W, P for the interstitial spaces 60. As shown in Figure 1, the interstitial spaces 60 have a warp dimension W that extends in a straight line between adjacent warp yarns 20 along the warp direction 4. The interstitial spaces 60 can have a weft dimension P that extends in a straight line between adjacent weft yarns 40 along the weft direction 6. The interstitial space dimensions W, P are generally perpendicular to the thickness T of the woven fabric. As explained below, one or more of the interstitial space dimensions decrease due to hydroentangling.

[0008] The plurality of warp yarns 20 and the plurality of weft yarns 40 are bulky around the compact interstitial spaces 60. The compact thickness and bulky warp and weft yarns give rise to a compact, soft, absorbent, hydroentangled woven fabric. The hydroentangling process as further described below creates the soft, compact structure. The compact, soft structure is because of bulk induced in the warp and weft yarns after during hydroentangling. It is believed that the added bulk is caused by fiber breakage or bending imparted by the hydroentangling process. The fiber breakage and bending has the effect of increasing the overall bulk of the yarn *in situ.* In one sense, the increased bulk is result of de-twisting of the yarn structure along portions of the weft and warp yarns between adjacent interlacing points. This, in turn, reduces the size of the interstitial spaces 60 creating a compact fabric in the width, length, and thickness directions, without changing the overall coverage or causing appreciable fabric shrinkage.

[0009] A number of different woven structures may define the woven fabric 10 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 warp direction 4; b) the weft direction 6; or both the warp direction 4 and weft direction 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 percale 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 an 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.

[0010] So call "co-insertion" techniques may be used 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 is in dashed lines in Figure 1. As used herein, the weft insertion path 19 extends along the weft direction 6 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.

[0011] "Co-insertion" is where multiple picks 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 twelve (12) weft yarns inserted during a single insertion event, i.e. along the weft insertion path 19. 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 disclosure are typically greater than about 80 and can be as high as about 1200 (or even higher). The thread count as used herein is the total number of yarns in square inch of fabric. The thread count in this context is based on total number of yarn ends. In other words, a plied yarn is considered one yarn for determining thread count.

[0012] 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 disclosure, the woven fabric has a warp end density between about 50 warp ends per inch and about 350 warp ends per inch. In one example, the warp end density is between about 50 and 150 warp ends per inch. In another example, the warp end density is between about 150 and 250 warp ends per inch. In another example, the warp end density is between about 250 and 350 warp ends per inch. Furthermore, the weft yarns are arranged to define a weft end density between about 50 weft yarns per inch and about 700 weft yarns per inch (or more). In one example, the weft yarn density is between about 100 and about 700 weft yarns per inch. In one example, the weft yarn density is between about 100 and about 300 weft yarns per inch. In another example, the weft yarn density is between about 300 and about 500 weft yarns per inch. In another example, the weft yarn density is 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 inch refers the 50 total weft yarns per inch 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 inch of fabric and 48 picks per inch.

[0013] The yarns (warp or weft) can have a range of counts for the different fibers and woven constructions as described herein. The yarn count can range between about 8 Ne (664 denier) to about 120 Ne (44.3 denier). In one example, the yarns can have a count in a range between about 8 Ne (664 denier). In one example, the yarns can have a count in a range between about 20 Ne (266 denier). In one example, the yarns can have a count in a range between about 30 Ne (177 denier). In one example, the yarns can have count in a range between about 40 Ne (133 denier). In another example, the yarns have a count of about 60 Ne (88.6 denier). In another example, the yarns have a count of about 70 Ne (75.9 denier). In another example, the yarns have a count of about 80 Ne (66.4 denier). In another example, the yarns have a count of about 100 Ne (53.1 denier). In another example, the yarns have a count of about 120 Ne (44.3 denier). For hydroentangled woven fabrics, the warp yarn counts may range from 20 Ne (266 denier) to about 100 Ne (53.1 denier). The weft yarn counts may range from 20 Ne (266 denier) to about 120 Ne (44.3.1 denier).

[0014] The hydroentangled woven fabric 10 can use different yarn constructions in the warp and weft components. For instance, the yarns (warp or weft) may be spun staple yarns or filament yarns. In accordance with one embodiment, the woven fabrics 10 include staple yarns formed from natural fibers or a blend of natural and synthetic fibers. In one example, the staple yarns are spun, cotton fiber yarns or blended yarns. While the staple yarn is preferably cotton, in certain alternative embodiments, the staple yarn can include cotton fibers blended with other natural or synthetic fibers. In such an example, the natural fibers could include silk, linen, flax, bamboo, hemp, wool, and the like. The synthetic fibers in this example are those fibers that result in fabric structures with good hand, drape, and softness. Such synthetic fibers include cellulosic fibers, including rayon fibers (e.g. Modal, Lyocell) or thermoplastic fibers, such as polyethylene terephthalate (PET) fiber, polylactic acid (PLA) fiber, polypropylene (PP) fibers, polyamide fibers, and microfiber staple fibers.

[0015] The staple yarns can be formed using a variety of staple yarn formation systems. For instance, staple yarn formation may include bale opening, carding, optionally combing, drafting, roving, and yarn spinning (yarn spinning processes are not illustrated) to the desired count and twist level. In some cases, the staple yarns can be plied into 2-ply, 3-ply, or 4-ply configurations. After yarn spinning, the staple yarns are wound into the desired yarn packages for weaving. In one example, ring spinning is the preferred spinning system. However, the staple yarns can be formed using open end spinning systems, rotor spun spinning systems, vortex spinning systems, core spinning yarns, jet spinning yarns, or compact spinning systems. Furthermore, the spinning system may include methods used form the Hygrocotton ®, disclosed in U.S. Patent No. 8,833,075, entitled "Hygro Materials for Use In Making Yarns And Fabrics," (the 075 patent). The 075 patent is incorporated by reference into the present disclosure. Accordingly, the staple yarns can be ring spun yarns, open end yarns, rotor spun yarns, vortex spun yarns, core spun yarns, jet spun yarns, or compact spun yarns. In another embodiment, the warp yarns can be Hygrocotton ® yarns marketed by Welspun India Limited. Furthermore, yarns can be formed as disclosed in the 075 patent. Preferably, the staple yarn is a ring spun yarn. The staple yarn, however, be any type of spun yarn structure.

[0016] For spun yarns, twist level is an important parameter in final yarn structure. Twist is imparted during spinning to bind the fibers together into yarn structure. The twist level of the yarn is typically optimized to provide the desired strength to aid in weaving. If the twist level is too high, the forces applied to fibers are high, which may cause in fiber breakage, and yarn break in the weaving process. With increased twist levels, the fibers in the yarn are more compact and softness and absorbency of the yarn is reduced. This can result in less than ideal softness in final woven products. Often this is addresses, to some extent, by adding hand modifiers during the dyeing and finishing process. There are, however, drawbacks, such as costs, increased waste water, energy usage, and other environmental concerns. Due to this tradeoff, there is a certain limitation of in woven fabrics in terms of softness and absorbency. The present disclosure addresses this tradeoff by permitting typical high twist yarns to be used during manufacturing, while achieving the result of having a low-twist yarn in the final fabric construction.

[0017] The woven fabric also includes continuous filament yarns. In one example, the continuous filament yarns are polyethylene terephthalate (PET) filament yarns. While the continuous filament yarns are primarily formed from PET, in alternative embodiments, the continuous filament, high bulk yarn are formed from other synthetic filaments, such as polylactic acid (PLA) fiber, polypropylene (PP) fibers, and polyamide fibers. Embodiments of the present disclosure include the continuous filament yarns dyed prior to fabric formation. For example, the continuous filament yarns can be a dope-dyed, continuous filament yarn. In another example, the continuous filament yarns can be dyed using a disperse dyes via package dyeing process (not shown). As used herein, a "dyed continuous filament yarn" means a yarn dyed prior to fabric formation whereby coloring agents are within the morphology of the filaments that form the yarns.

[0018] The hydroentangled woven fabric 10 can use different yarn constructions in the warp and weft components. In one example, the warp yarns are staple spun yarns (cotton or any fiber blends) and the weft yarns may include staple yarns. In one example, the warp yarns are continuous filament yarns and the weft yarns are staple spun yarns. In one example, the weft yarns are continuous filament yarns and the warp yarns are staple spun yarns. In another example, the warp yarns include staple yarns and filament yarns and the weft yarns include staple yarns and filament yarns.

[0019] While the yarns are described in relation to the process used to make them, one of skill in the art will appreciate that the each staple yarn described above has structural differences unique to each yarn formation system. Thus, the description of the yarns above is also a description of yarn structure.

[0020] The hydroentangled woven fabric 10 has a range of basis weights. For instance, the hydroentangled woven fabric has a basis weight in the range of about 100 grams per square meter to about 330 grams per square meter. In one embodiment, the basis weight of the hydroentangled woven fabric is in the range of about 150 grams per square meter to about 250 grams per square meter. In another embodiment, the basis weight is in the range of about 170 grams per square meter to about 200 grams per square meter. The basis weight referred to herein can be determined according to ISO 9073-1:1989, Textiles --Test methods for nonwovens -- Part 1: Determination of mass per unit area."

[0021] Turning now to Figures 3 and 4, a process 100 and system 200 for manufacturing the hydroentangled woven fabric 10 is illustrated. The process 100 as illustrated is designed to form a hydroentangled woven fabric 10. In general, the process 100 includes yarn formation 110, warping 120, weaving 140, greige processing 140, hydro-entangling 170, dyeing & finishing 180, and converting 190. It should be appreciated that certain steps are optional, such as all processing operations except for hydro-entangling. It should be appreciated that the process may vertical integrated and include process operation from yarn formation 110 through the converting 190 as illustrated. Alternatively, the process may include treating a preformed griege woven fabric. The manufacturing system shown in Figure 4 includes an unwinder 210, a straightening unit 220, a conveying member 242, a hydroentangling unit 230, conveying member 244, drying unit 250, and a winding unit 260.

[0022] Turning to Figure 3, a method 100 of making woven fabric may include a yarn formation 110. Yarn formation

110 for the warp yarns can include staple yarn formation and/or filament yarn formation. Staple yarn formation may utilize any number of staple yarn formation systems and sub-systems as described above with respect to the staple yarns. Filament yarn formation may involve melt spinning continuous filament yarns and texturizing the filament yarns

[0023] After yarn formation 110, the yarns are warped in a warping step 120. Warping 120 is where the warp yarn ends are removed from their respective yarn packages, arranged in a parallel form, and wound onto a warp beam, as is known to a person of skill in the weaving arts. The warping step 120 also includes a sizing step where a sizing agent is applied to each warp yarn to aid in fabric formation. The warping step 120 results in a warp beam of yarns that can be positioned on a mounting arm of a weaving loom so that the warp yarns can be drawn through the loom components according to the desired weave design.

[0024] Continuing with Figure 3, fabric formation 140 includes weaving warp yarns and weft yarns into a griege woven fabric G using a weaving loom. More specifically, in the fabric formation step 140, the warp yarns are drawn-in (not shown) through various components of a weaving loom, such as drop wires, heddle eyes attached to a respective harness, reed and reed dents, in a designated order as is known in the art. Next, weaving proceeds through fabric a formation phase. The fabric formation phase creates a shed with the warp yarns that the weft or picks are inserted through across the width direction of the loom to create the desired woven fabric construction. Various shedding motions may be used, for example, such as cam, dobby, or jacquard shedding motions. The formation phase can utilize different weft insertion techniques, including air-jet, rapier, or projectile type weft insertion techniques.

[0025] During the formation phase of the weaving step 140, weft yarns 40 are interwoven with the warp yarns 20 to define the woven design construction. Exemplary fabric woven constructions can include but are not limited to: plain weaves; basket weaves, satins (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); rib weaves (e.g. 2x1 rib weave; 2x2 rib weave; or 3x1 rib weave); twill weaves, and oxford weaves. In one example, the woven fabric is a plain weave. In another example, the woven fabric is a satin weave.. In another example, the woven fabric is a percale weave. In another 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 another example, the woven fabric is a 4/1 satin jacquard weave. The weaving step forms a woven fabric with a warp end density between 50 warp ends per inch to about 300 warp ends per inch. The weft yarns can be inserted in such a manner to define a weft or pick density between about 50 picks per inch to about 300 picks per inch.

[0026] After the fabric formation step 140, an optional griege processing step 150 may occur. Greige processing may include singing, desizing (where appropiate), washing, bleaching, and stretching the fabric. After the griege processing step 150, the griege woven fabric G is introduced to the hydroentangling unit 230.

[0027] Referring still to Figures 3 and 4, the hydroentangling step 170 applies high pressure water jets to the griege fabric G with a hydro-entanglement unit. As can be seen in Figure 4, the hydro-entanglement unit 220 includes one or more high-pressure module 232a-234d. Each high pressure module 232a-234d includes a water jet nozzle assembly 234a-234d, respectively. The number of water nozzle jet assemblies can be about 2 to about 10. Four nozzle assemblies are shown for illustrative purposes. More than four or less than four could be used. Each nozzle assembly 234a-234d is configured to eject a plurality of high-pressure water jets into griege woven fabric G. Each high pressure module 234a-234d includes a perforated forming cylinder 236a-236d that carries greige fabric G along each water jet nozzle assembly 234a-234d where high pressure jets are ejected into the griege fabric G, thereby forming the hydroentangled woven fabric 10. In accordance with an embodiment of the present disclosure, the high-pressure water jets are applied to fabric G at a pressure of about 100 bar to about 400 bar. After passeing through the fabric the water passes trough the fabric and enters the vacuum chamber through perforrated sleeve of the cylinders. Following application of the water jets to the fabric G, the second conveyer member 244 advances the fabric toward the next process step.

[0028] The hydroentangling step 170 changes the structure of the greige fabric G. As can be seen Figures 5A, 6A and 7A, the interlacing of the warp yarns with the weft yarns define a woven fabric G having first interstitial spaces 60a, each of which have a first dimension P1 that extends in a straight line between adjacent warp yarns. The first dimension P1 is aligned with the weft direction and is generally perpendicular to the thickness T of the woven fabric as explained above. In one example, the first dimension P1 is aligned with the weft direction as illustrated in Figures 5A, 6A, and 7A. Applying high pressure water jets to the woven fabric G to define the hydroentangled woven fabric 10 creates new, second interstitial spaces 60b between the warp yarns, as illustrated in Figures 5B, 6B, and 7B. The second interstitial spaces 60b have a second dimension P2 that is smaller than the first dimension P1. The second dimension have P2 extends in a straight line between adjacent warp yarns (or between adjacent weft yarns) along the weft direction and is generally perpendicular to the thickness T of the woven fabric. The extent of how much smaller the second dimension of the interstitial space is compared to the first dimension is dependent on a number of factors, including yarn count, weave pattern, beat-up forces, and pick insertion techniques. In general, however, the applying water jets through the hydroentangling processes decreases the size of the interstitial spaces 60. Furthermore, as explained below, the resulting fabric has a more compact thickness T than what would otherwise be available if hydroentangling is not used to treat the griege fabric.

[0029] During hydroentangling, the high pressure water jets modify the yarn structures in the fabric. The high pressure water jets penetrate inside the yarn structure, which causes the fibers to realign within yarn structure, partially detwisting the yarn structure and changing the fiber orientation. Without being bound by any particular theory, it is believed that applying the high pressure water jets comprising break and/or bend at least a portion of the fibers in the plurality of warp yarns and the plurality of weft yarns. This can result in de-twisting during the hydroentangling step. In one example, the plurality of warp and weft yarns has a first twist level in griege fabric state (or even prior to fabric formation). After hydroentangling, the twist level of the yarns decreases. Specifically, the plurality of warp and weft yarns has a second twist level that is lower than the first twist level. As the twist level decreases, the yarns are more open and bulky. This, in turn, decreases the size of the interstitial spaces as described above. See e.g. Figures 5A compared to Figure 5B, Figure 6A compared to Figure 6B, and Figure 7A compared to Figure 7B. Due to change in fiber orientation and related detwisting, the yarn structure is more open and can can absorb more water or moisture. The openness of the yarn structure can also entrap more air, impacting the thermal insulative properties of the fabric. The openness of yarn structure also make the the fabric more soft and breathable. The postive impact of better absorbancy, thermal insulation, softness, and breathability result in a more comfortable woven fabric than would otherwise be available without the water jet treatments as described herein. Tables 1 and 2 below illustrate some exemplary propeties of woven fabrics treated with the high pressure water jet in accordance with the inventive concepts of the present disclosure.

[0030] Referring still to Figures 3 and 4, in step 170 the hydroentangled woven fabric 10 is introduced to a drying unit 250 via conveyor member 244 to remove moisture from the hydroentangled woven fabric 10. Following the drying, the hydroentangled woven fabric may have a basis weight in the range of about 50 grams per square meter to about 330 grams per square meter. In one embodiment, the basis weight of the hydroentangled woven fabric is in the range of about 150 grams per square meter to about 250 grams per square meter. In another embodiment, the basis weight is in the range of about 170 grams per square meter to about 200 grams per square meter.

[0031] The process 100 includes an optional dying & finishing step 180 after hydroentangling 170. The dyeing and finishing step 180 applies color and one or more functional agents to the fabric. In an embodiment with cotton staple yarns, the cotton staple yarns are dyed with reactive dyes using a pad dry, pad steam, cold pad batch methods. Step 180 may also include applying a composition including one or more of the functional agents to the woven fabric. The functional agents may include a softener, antimicrobial agent, etc. Next, excess moisture is removed the woven fabric by advancing the fabric through a heating machine. Heating machines may be heated steam, infrared, hot air, surface rolls, hot oil can, through-air ovens, and like machines. After drying, the woven fabric may be sanforized and calendared to adjust the hand and better control shrinkage.

[0032] Continuing with Figure 3, after the dyeing and finishing step 180, the woven fabric is converted into the bedding article in step 190. As illustrated, the converting step 190 may include cutting the woven fabric to the size for the intended bedding article.

[0033] Figures 5A-7B are images of woven fabric examples A-F further described below. Figures 5A, 6A, and7A illustrate various woven fabrics taken prior to hydroentangling. Figures 5B, 6B, and 7B illustrate the same fabrics shown in Figures 5A, 6A, and 7A but taken after hydroentangling. The following examples have been prepared to illustrate various attributes of the hydroentangled woven fabric 10 described herein.

[0034] Example A is a 120 thread count woven fabric with a percale construction. The warp yarns are 20s open end yarns. The weft yarns are 20s open end yarns. The warp end density is 65 ends per inch (EPI) and the weft density is 60 picks per inch (PPI). A conventional sizing was used to prepare the warp yarns. The fabric was manufactured on an air jet loom. Example B is the same fabric as example A except that the fabric was subjected to hydroentangling treatment as described above. In this case, four water jet nozzles were used and the pressures were between 90 bar and 140 bar across the four water jet nozzles. Figure 5A illustrates example A and Figure 5B illustrates example B.

[0035] Example C is a 400 thread count woven fabric with 4/1 satin construction. The warp yarns are 80s ring spun yarns. The weft yarns were 80s ring spun yarns. The warp end density is 205 end per inch (EPI) and the weft density is 66/3 picks per inch (PPI) using co-insertion techniques. The actual weft density is therefore 198 picks per inch (PPI) (e.g. 66*3=198). A conventional sizing was used to prepare the warp yarns. The fabric was manufactured on an air jet loom. Example D is the same fabric as example C except that the fabric was subjected to hydroentangling treatment as described above. In this case, four water jet nozzles were used and the pressures were between 90 bar and 140 bar across the four water jet nozzles. Figure 6A illustrates example C and Figure 6B illustrates example D.

[0036] Example E is a 400 thread count woven fabric with oxford construction. The warp yarns are 80s ring spun yarns. The weft yarns were 80s ring spun yarns. The warp end density is 228 end per inch (EPI) and the weft density is 84/2 picks per inch (PPI) using co-insertion techniques. The actual weft density is therefore 168 picks per inch (PPI) (e.g. 84*2=168). A conventional sizing was used to prepare the warp yarns. The fabric was manufactured on an air jet loom. Example F is the same fabric as example E except that the fabric was subjected to hydroentangling treatment as described above. In this case, four water jet nozzles were used and the pressures were between 90 bar and 140 bar across the four water jet nozzles. Figure 6A illustrates example E and Figure 6B illustrates example F.

[0037] Table 1 below summarize comparative tests conducts for examples A through F.

Table 1

Test Method		Examp le A	Examp le B	Examp le C	Exampl e D	Exampl e E	Examp le F
Thread Count	ASTM D3775	120	118	408	406	396	396
Weight (gsm)	ASTM D3776	161	148	132	146	122	124
Shade Change	AATCC-61 2A	4 to 5	4 to 5	4 to 5	4 to 5	4 to 5	4 to 5
Color Fastness-Stain	AATCC-61 2A	4 to 5	4 to 5	4 to 5	4 to 5	4 to 5	4 to 5
Fastness To Crocking-Dry	AATCC-8/116	4 to 5	4 to 5	4 to 5	4 to 5	4 to 5	4 to 5
Fastness To Crocking-Wet		4 to 5	4 to 5	4 to 5	4 to 5	4 to 5	4 to 5
Dimension al Stability-Warp	AATCC-135/150	-3%	-3%	-3%	-3%	-3%	-3%
Dimension al Stability-Weft		-2%	-3%	-2%	-2%	-2%	-2%
Tensile Strength Warp (LBS)	ASTM D5034	40	47	75	89	70	76
Tensile Strength Weft (LBS)		40	49	56	64	42	54
Tearing Strength - Warp (LBS)	ASTM D1424	2	2.51	5	6	2	2.12
Tearing Strength - Weft (LBS)		2	2.77	7	9	2	2.09
-Seam Strength Warp (LBS)	ASTM D1683	50	60	22	60	32	46
Seam Strength - Weft (LBS)		38	54	31	58	40	60
Pilling Resistance (100 Cycles)	ASTM D4970	3	3	3	3	3	3
Dp Rating	AATCC 124	2	2.5	2.5	3	2	2.5
Thermal Resistance (Rt)	*C·m2/W	0.2034	0.2353	0.2076	0.2456	0.2093	0.2489

Table 2

Moisture Wicking AATCC 197		
	Example A	Example B
TIME	WARP (cm)	WARP (cm)
5 MIN	4	5.2
10 MIN	6.4	7.6

(continued)

Moisture Wicking AATCC 197		
	Example A	Example B
TIME	WARP (cm)	WARP (cm)
15 MIN	7.3	8.7
20 MIN	8.3	10.2
25 MIN	8.5	10.5
30 MIN	8.8	12
	Example C	Example D
TIME	WARP (cm)	WARP (cm)
5 MIN	6.5	7.5
10 MIN	8.7	9.5
15 MIN	10	12.3
20 MIN	10.8	13.2
25 MIN	11.2	14
30 MIN	11.7	15.6
	Example E	Example F
TIME	WARP (cm)	WARP (cm)
5 MIN	4.9	5.9
10 MIN	6.5	7.9
15 MIN	7.5	9.5
20 MIN	8.3	10.6
25 MIN	8.7	11.5
30 MIN	9.1	12.5

[0038] Tables 1 and 2 include data of examples with and without hydroentangling. In most tests performed, the properties are not significantly different when comparing untreated (Examples A, C, E) and treated woven fabrics (Examples B, D, F). This is generally positive in that the end-use properties required for bedding applications are achieved with the treated examples B, D, and F. However, there are a few properties where the unique structural differences can be seen in the data. For instance, the thermal resistance (Rt) of the woven fabrics improves after hydroentangling. As shown in Table 1, in each case, hydro-entangling increases the thermal resistance. In comparing Figures 5A, 6A, 7A, to Figures 5B, 6B, and 7B, it can be seen that the interstitial spaces/ porosity between warp and weft yarn interlacements decreases. However, it also appears that the yarns are more open, which helps to improve the thermal resistance. Due to this, the treated woven fabrics have better insulation under cold conditions. After treating the fabric with the waterjets, the yarn structures are opened and the fibers are in a more relaxed state from its original condition in. This is believed to result in less wrinkles and improved durable press (DP) values after treatment.

[0039] Furthermore, after hydroentangling, the moisture wicking of the fabric improved. For instance, in example C (400TC Satin 100% Cotton), the wicking observed was 11.7 cm after 30 minutes according to AATCC 197. In comparison, when the same fabric is hydroentangled, the moisture wicking improves to 15.6 cm after 30 minutes. The improvement of moisture wicking may help absorb sweat quickly as well as to evaporate the absorbed sweat more quickly. This helps to enhance the comfort properties.

[0040] The examples and data illustrate that yarn structure is more open. Since the yarn structure open, the fabric structure is more porous and can hold more air. This helps to improve the thermal resistance, i.e. improving the comfort factor under cooler environmental conditions. The examples and data illustrate also illustrate that the wicking and absorbency of the fabric is increased, which helps to quickly absorb the moisture and to evaporate absorbed moisture more quickly. This can manifest in a cool comfort feeling in use.

[0041] The inventive concepts disclosed herein result in a woven fabric with enhanced comfort properties. In accordance with the inventive concepts disclosed herein, a typical woven fabric has improved moisture wicking, better thermal insulation, and softer hand-feel. With these enhancements, the overall comfort of the fabric increases.

[0042] The present disclosure includes the following inventive concepts:

Embodiment 1 is a method for forming a hydroentangled woven fabric, the method comprising:

weaving a plurality of warp yarns with a plurality of weft yarns to define a woven fabric having first interstitial spaces between the warp yarns and the weft yarns, wherein the first interstitial spaces have a first dimension that is perpendicular to a thickness of the woven fabric;
applying high pressure water jets to the woven fabric to define the hydroentangled woven fabric having second interstitial spaces between the warp yarns and the weft yarns, wherein the second interstitial spaces have a second dimension that is perpendicular to the thickness and that is smaller than the first dimension; and
drying the hydroentangled woven fabric to substantially remove moisture from the hydroentangled woven fabric, wherein the hydroentangled woven fabric defines a) a plurality of compact interstitial spaces, and b) a compact thickness that extends in a direction from a first side of the hydroentangled woven fabric to a second side of the hydroentangled woven fabric.

Embodiment 2 is a method of Embodiment 1, wherein the plurality of water jets assemblies emit water jets at a pressure between about 50 bars to about 400 bars.

Embodiment 3 is method of Embodiment 1 or 2, further comprising, prior to weaving: forming the plurality of warp yarns; and forming the plurality of weft yarns.

Embodiment 4 is a method of Embodiment 1, 2, or 3, wherein applying the high pressure water jets comprising breaking at least a portion of the fibers in the plurality of warp yarns and the plurality of weft yarns.

Embodiment 5 is a method of Embodiment 1, 2, 3, or 4, wherein the hydroentangled woven fabric has a) a warp end density between about 50 warp ends per inch and about 350 warp ends per inch, and b) a weft end density between about 50 weft yarns per inch and about 700 weft yarns per inch.

Embodiment 6 is a method of Embodiment 1, 2, 3, 4, or 5, wherein the hydroentangled woven fabric has a thread count between 80 and 1200.

[0043] It will be appreciated by those skilled in the art that various modifications and alterations of the present disclosure can be made without departing from the broad scope of the appended claims. Some of these have been discussed above and others will be apparent to those skilled in the art. The scope of the present disclosure is limited only by the claims.

Claims

1. A hydroentangled woven fabric, comprising:

a plurality of warp yarns;
a plurality of weft yarns interwoven with the plurality of warp yarns to define the hydroentangled woven fabric having a first side and a second side opposite the first side;
a plurality of compact interstitial spaces between the plurality of warp yarns and the plurality of weft yarns, wherein the plurality of warp yarns and the plurality of weft yarns are bulky around the compact interstitial spaces; and
a compact thickness that extends in a direction from the first side of the hydroentangled woven fabric to the second side of the hydroentangled woven fabric,
wherein the compact thickness and bulky warp and weft yarns give rise to a compact and moisture wicking hydroentangled woven fabric.

2. The hydroentangled woven fabric of claim 1, having a basis weight between 100 grams per square meter and 400 grams per square meter for a thickness that ranges between 0.5 mm and 1.5 mm.

3. The hydroentangled woven fabric of claim 1 or claim 2, wherein the hydroentangled woven fabric is treated with high pressure water jets to impart bulk to the plurality of warps yarns and to the plurality of weft yarns while giving rise to the compact thickness.

4. The hydroentangled woven fabric of any of claims 1 to 3, wherein the plurality of bulky warp yarns and the plurality of bulk weft yarns each comprise a plurality of broken fibers.

5. The hydroentangled woven fabric of any of claims 1 to 4, wherein the bulk warp yarns and the bulky weft yarns are arranged to define a) a warp end density between about 50 warp ends per inch and about 350 warp ends per inch, and b) a weft end density between about 50 weft yarns per inch and about 700 weft yarns per inch.

6. The hydroentangled woven fabric of any of claims 1 to 5, wherein the hydroentangled woven fabric has a thread count between 80 and 1200.

7. The hydroentangled woven fabric of any of claims 1 to 6, wherein the plurality of warp yarns comprises natural fibers or synthetic fibers.

8. The hydroentangled woven fabric of any of claims 1 to 7, wherein the plurality of weft yarns comprises natural fibers or synthetic fibers.

9. The hydroentangled woven fabric of any of claims 1 to 8, wherein the plurality of warp yarns comprises a blend of natural fibers and synthetic fibers.

10. The hydroentangled woven fabric of any of claims 1 to 9, wherein the plurality of weft yarns comprises a blend of natural fibers and synthetic fibers.

11. The hydroentangled woven fabric of any of claims 1 to 10, wherein the hydroentangled woven fabric has a wicking distance of at least 5.0 centimeters during a time period of five minutes according to test method AATCC 197.

12. The hydroentangled woven fabric of any of claims 1 to 11, wherein the hydroentangled woven fabric has a wicking distance of at least 10.0 centimeters during a time period of twenty minutes per according to test method AATCC 197.

13. The hydroentangled woven fabric of any of claims 1 to 12, wherein the hydroentangled woven fabric has a wicking distance of at least 12 centimeters during a time period of thirty minutes per according to test method AATCC 197.

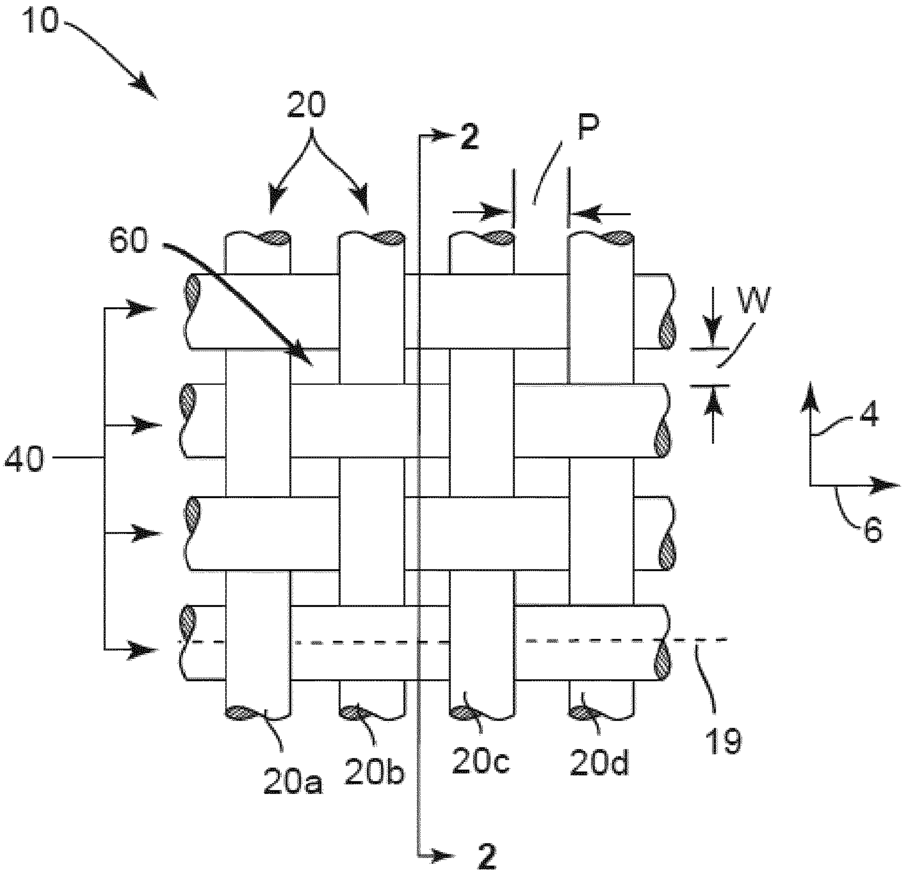

FIG. 1

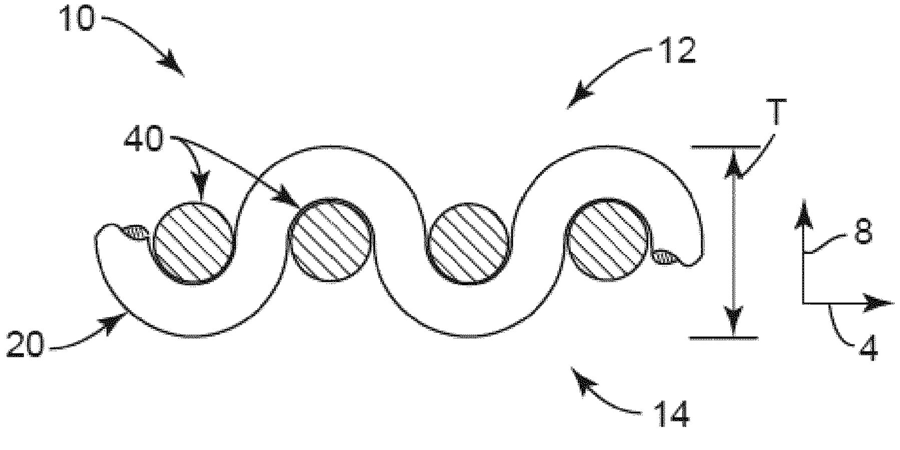

FIG. 2

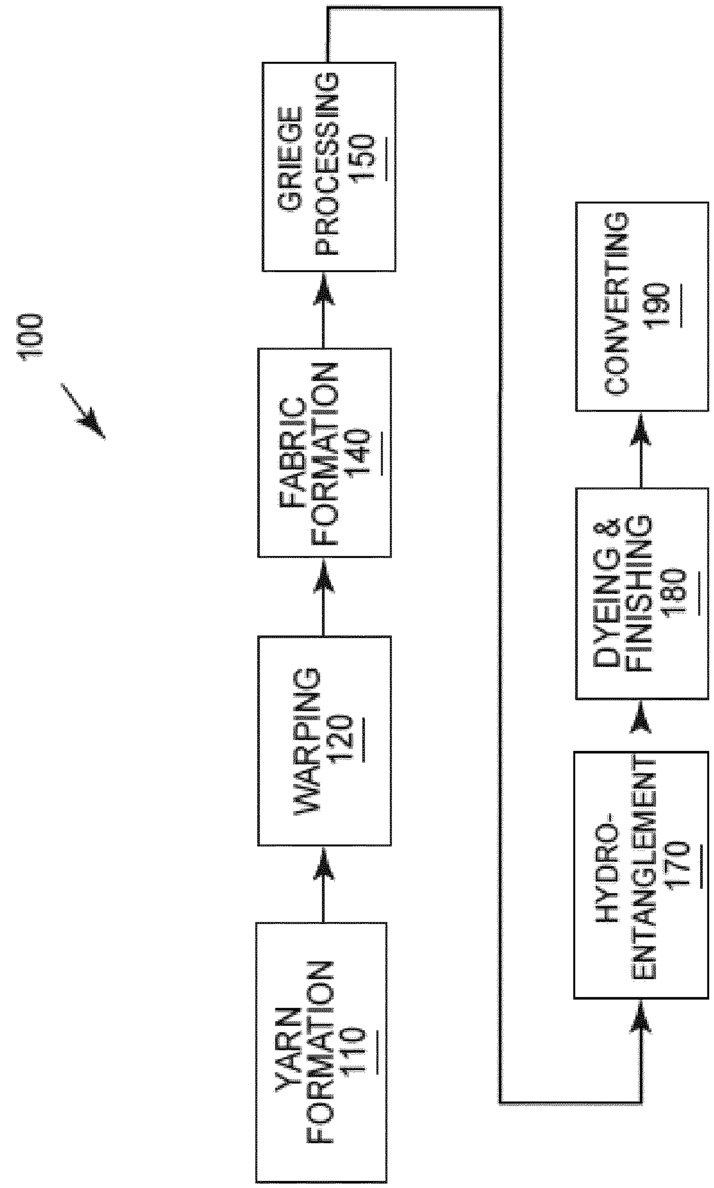
100
YARN FORMATION 110
WARPING 120
FABRIC FORMATION 140
GRIEGE PROCESSING 150
HYDRO-ENTANGLEMENT 170
DYEING & FINISHING 180
CONVERTING 190

FIG. 3

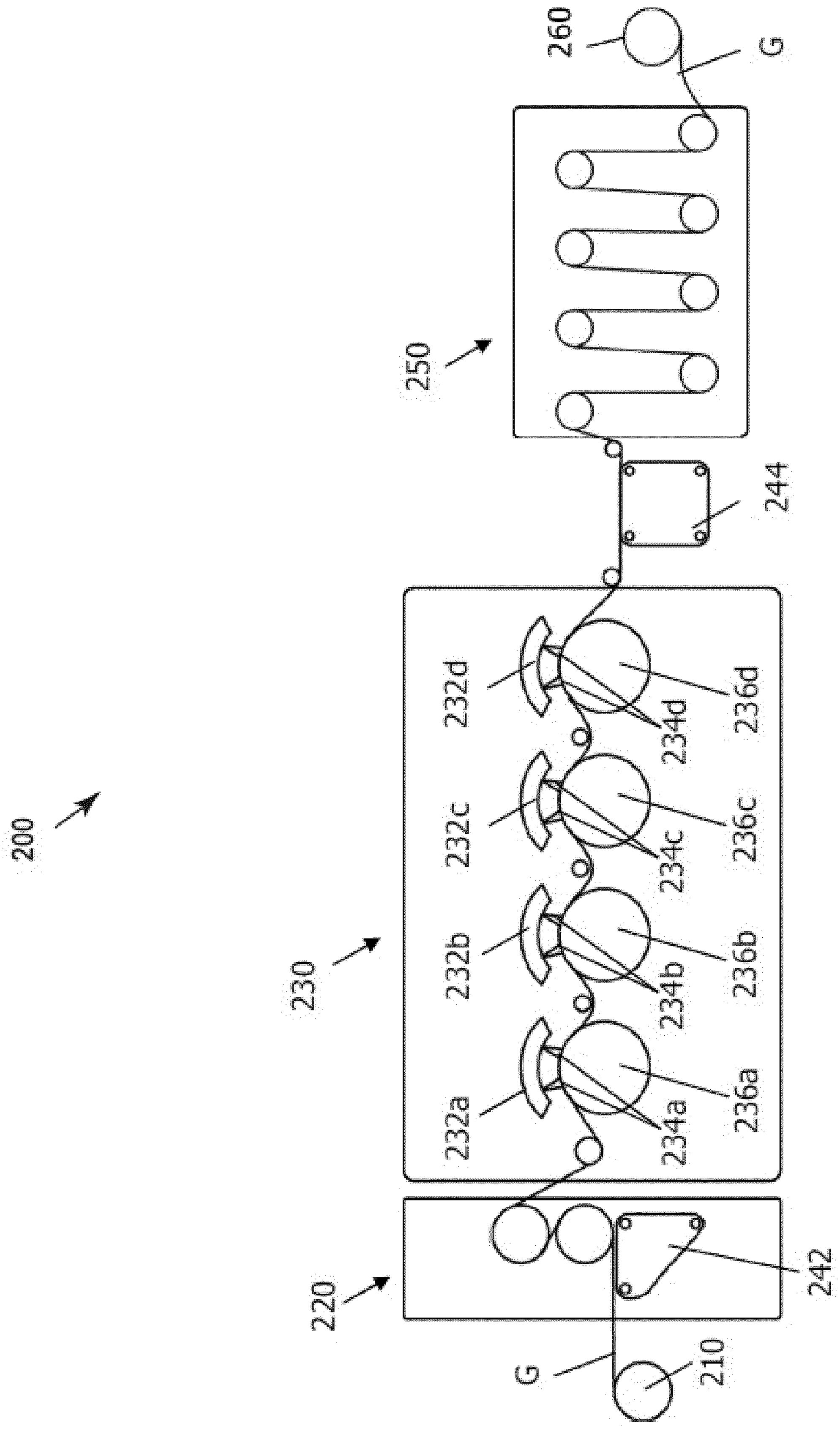
200
230
220
232a
232b
232c
232d
234a
234b
234c
234d
236a
236b
236c
236d
242
244
250
260
210
G
G

FIG. 4

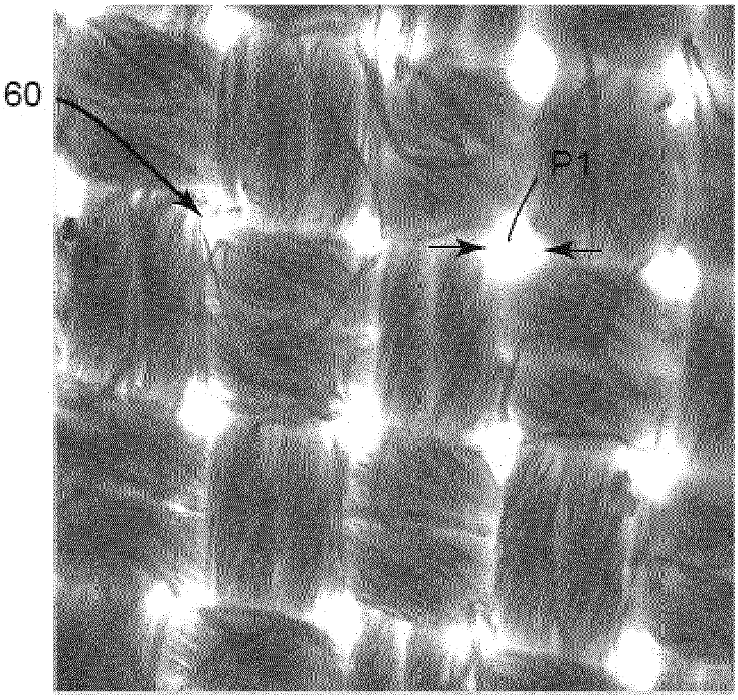

FIG. 5A

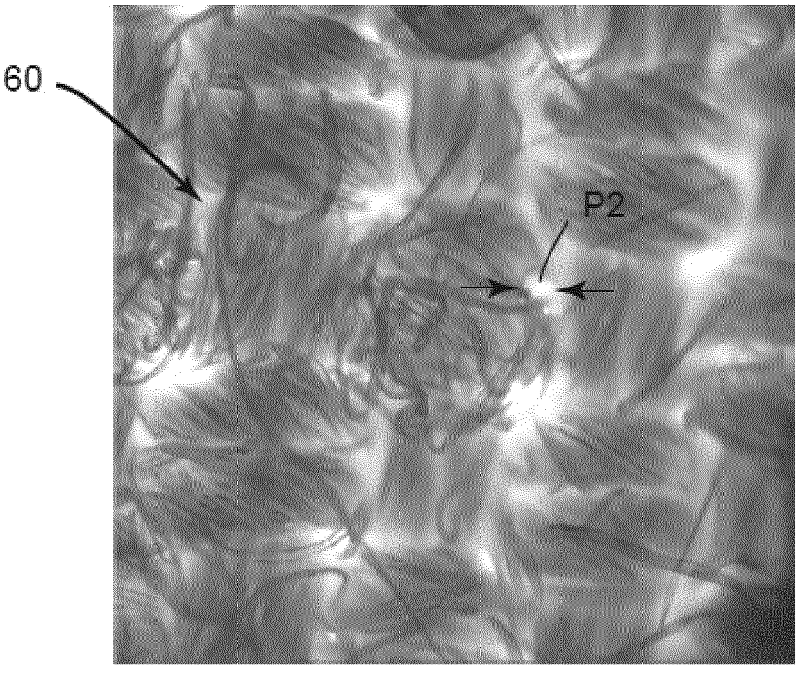

FIG. 5B

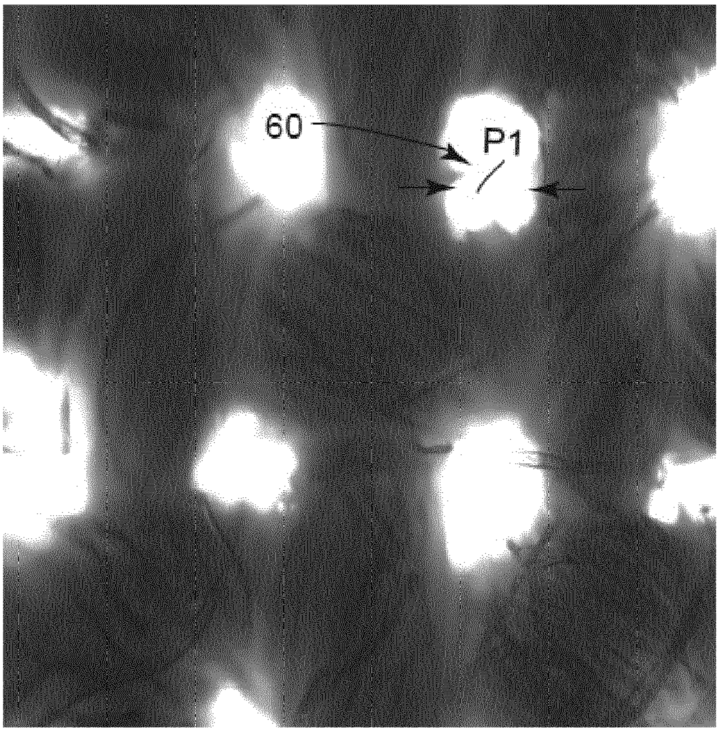

FIG. 6A

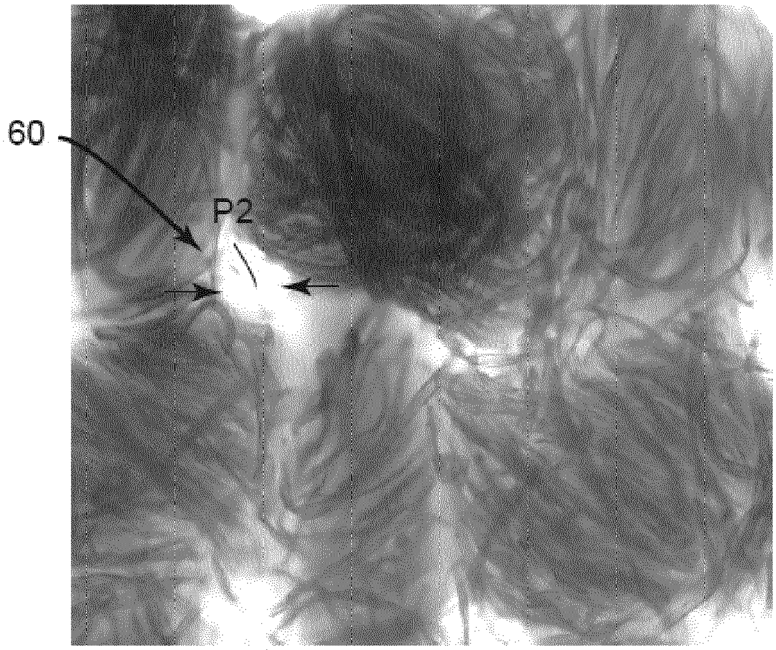

FIG. 6B

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EUROPEAN SEARCH REPORT

Application Number
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D06C
D03D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	26 September 2018	Louter, Petrus

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