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(54) Title: NONWOVEN COMPOSITE INCLUDING REGENERATED CELLULOSE FIBERS

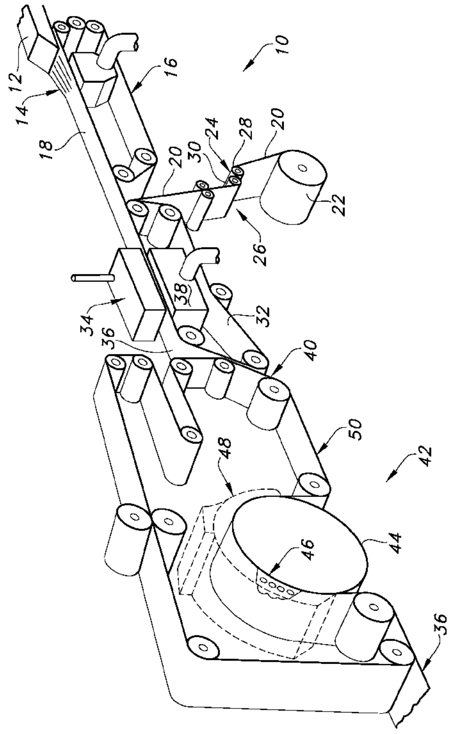

FIG. 1

(57) Abstract: The present invention provides a soft, bulky, and absorbent hydroentangled nonwoven including regenerated cellulose fibers and staple or wood pulp fibers and a method of making the same that includes the steps of a) placing regenerated cellulose fibers on a forming surface; b) depositing staple or wood pulp fibers on the regenerated cellulose fibers; c) hydroentangling the regenerated cellulose fibers and the staple or wood pulp fibers together to form a hydroentangled composite; d) drying the hydroentangled composite; then, e) creping the hydroentangled composite with a frothed creping solution or dispersion.

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NONWOVEN COMPOSITE INCLUDING REGENERATED CELLULOSE FIBERS

CROSS-REFERENCE to RELATED APPLICATION

This application claims the benefit of U.S. Patent Application Serial Number 12/979852 filed December 28, 2010, the entirety of which is incorporated by reference herein.

BACKGROUND OF THE INVENTION

Hydroentangled nonwoven composites having absorbent fibers hydraulically entangled with a synthetic fiber web are known in the art, and are taught in various patents and publications including, for example, U.S. Patent 4,808,467 to Suskind and U.S. Patent 5,284,703 to Everhart et al. Hydroentangled nonwoven composites made from absorbent fibers which are entangled with the synthetic fiber web are known in the art for being durable, having abrasion resistance while still being absorbent.

These hydroentangled nonwoven composites may be creped to increase bulk and softness of the hydroentangled nonwoven composite. However, during the creping process heat from the creping dryer may have a detrimental effect on synthetic fibers, such as polypropylene fibers, that are susceptible to softening and melting at the drying temperatures. As a result there is a need in the art for hydroentangled nonwoven composites which are more suitable for creping at higher temperatures.

SUMMARY OF THE INVENTION

In one embodiment, a direct-formed nonwoven including regenerated cellulose fibers and staple or wood pulp fibers is formed by the following steps: a) placing regenerated cellulose fibers on a forming surface; b) depositing staple or wood pulp fibers on the regenerated cellulose fibers; c) hydroentangling the regenerated cellulose fibers and the staple or wood pulp fibers together to form a hydroentangled composite; d) drying the hydroentangled composite; then, e) creping the hydroentangled composite with a frothed creping solution or dispersion. In one embodiment, the regenerated cellulose fibers may have a basis weight from about 10 to about 20 grams per square meter. In another embodiment, the regenerated cellulose fibers may be continuous fibers. In a further embodiment, the staple or wood pulp fibers have a basis weight from about 30 to about 150 grams per square meter.

In one aspect, the creping step may include the steps of: a) positioning an additive composition applicator adjacent to a hot non-permeable dryer surface; b) applying the frothed dispersion or frothed solution including an additive composition to the dryer surface; c) allowing the frothed dispersion or frothed solution to convert to an adhesive film; d) directly bonding the hydroentangled composite to the adhesive film; and e) scraping the bonded hydroentangled composite and adhesive film from the dryer surface. In one embodiment, the additive composition may further include a foaming agent. In another embodiment, the additive composition may include a hydroxypropyl cellulose solution. In one embodiment, the hot non-permeable dryer surface may have a temperature exceeding about 300 degrees Fahrenheit, optionally between about 500 and about 550 degrees Fahrenheit. In another embodiment, the adhesive film may be a substantially continuous adhesive film.

In another embodiment, an integrated composite fabric includes greater than about 5 weight percent and less than about 30 weight percent continuous regenerated cellulose filaments and greater than about 70 weight percent and less than about 95 weight percent wood pulp fibers. In one embodiment, the integrated composite fabric may have an absorbent capacity of greater than 5.6 g/g. In another embodiment, the integrated composite fabric may have a softness of 4 logs or better than a similar integrated composite fabric with polypropylene filaments instead of regenerated cellulose filaments. In a further embodiment, the wood pulp fibers may be discontinuous fibers. In an even further embodiment, the continuous regenerated cellulose filaments are Lyocell filaments. In another embodiment, the continuous regenerated cellulose filaments may be spunbond filaments.

In another embodiment, a method of making a direct-formed nonwoven including regenerated cellulose fibers and wood pulp fibers includes the steps of: a) placing the regenerated cellulose fibers on a forming surface; b) depositing the wood pulp fibers on the regenerated cellulose fibers; c) hydroentangling the regenerated cellulose fibers and the wood pulp fibers together to form a hydroentangled composite; d) drying the hydroentangled composite; then, e) creping the hydroentangled composite with a frothed creping solution or dispersion. In a further embodiment, the regenerated cellulose fibers may be continuous fibers.

In another embodiment, the creping step may include the steps of: a) positioning an additive composition applicator adjacent to a hot non-permeable dryer surface; b) applying the frothed dispersion or frothed solution comprising an additive composition to the dryer surface; c) allowing the frothed dispersion or frothed solution to convert to an adhesive film; d)directly bonding the hydroentangled composite to the adhesive film; and e) scraping the bonded hydroentangled composite and adhesive film from the dryer surface. In one embodiment, the additive composition may further include a foaming agent. In another embodiment, the additive composition may include a hydroxypropyl cellulose solution. In one embodiment, the hot non-permeable dryer surface may have a temperature exceeding about 300 degrees Fahrenheit, optionally between about 500 and about 550 degrees Fahrenheit. In another embodiment, the adhesive film may be a substantially continuous adhesive film.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an exemplary process for preparing the nonwoven composite of the present invention.

DEFINITIONS

As used herein the term “staple fibers” means discontinuous fibers made from regenerated cellulose or synthetic polymers such as polypropylene, polyester, post consumer recycle (PCR) fibers, polyester, nylon, and the like, and those not hydrophilic may be treated to be hydrophilic. Staple fibers may be cut fibers or the like. Staple fibers can have cross-sections that are round, bicomponent, multicomponent, shaped, hollow, or the like. Typical staple fiber lengths utilized for this invention are 3 to 12 mm with deniers from 1 to 6 denier per fiber (dpf).

As used herein the term “pulp fibers” means fibers from natural sources such as woody and non-woody plants. Woody plants include, for example, deciduous and coniferous trees. Non-woody plants include, for example, cotton, flax, esparto grass, milkweed, straw, jute hemp, and bagasse.

As used herein the term "nonwoven web" means a web having a structure of individual fibers or threads which are interlaid, but not in an identifiable manner, as in a knitted fabric. Nonwoven webs have been formed from many processes such as, for example, meltblowing processes, spunbonding processes, and bonded carded web processes. The basis weight of nonwoven webs is usually expressed in ounces of material per square yard (osy) or grams per square meter (gsm) and the fiber diameters are usually expressed in microns or denier per fiber (dpf). (Note that to convert from osy to gsm, multiply osy by 33.91).

As used herein the term "microfibers" means small diameter fibers having an average diameter not greater than about 75 microns, for example, having an average diameter of from about 0.5 microns to about 50 microns, or more particularly, microfibers may have an average diameter of from about 0.5 microns to about 40 microns. Another frequently used expression of fiber diameter is denier, which is defined as grams per 9000 meters of a fiber. For example, the diameter of a polypropylene fiber given in microns may be converted to denier by squaring, and multiplying the result by 0.00629, thus, a 15 micron polypropylene fiber has a denier of about 1.42 (15.sup.2 × 0. 00629=1.415).

As used herein the term "spunbond" refers to a process in which small diameter fibers are formed by extruding molten thermoplastic material as filaments from a plurality of fine, usually circular capillaries of a spinnerette with the diameter of the extruded filaments then being rapidly reduced as by the process shown, for example, in U.S. Pat. No. 4, 340,563 to Appel et al., and U.S. Pat. No. 3,692,618 to Dorschner et al., U.S. Pat. No. 3,802,817 to Matsuki et al., U.S. Pat. Nos. 3,338,992 and 3, 341,394 to Kinney, U.S. Pat. Nos. 3,502, 538 to Levy, U.S. Pat. No. 3,502, 763 to Hartman, and U.S. Pat. No. 3,542,615 to Dobo et al. Spunbond fibers are generally continuous and have diameters larger than 7 microns, more particularly, between about 10 and 30 microns. Spunbond fibers are generally not tacky when they are deposited onto the collecting surface.

As used herein the term "meltblown" refers to a process in which fibers are formed by extruding a molten thermoplastic material through a plurality of fine, usually circular, die capillaries as molten threads or filaments into converging high velocity gas (e.g. air) streams which attenuate the filaments of molten thermoplastic material to reduce their diameter, which may be to microfiber diameter. Thereafter, the meltblown fibers are carried by the high velocity gas stream and are deposited on a collecting surface to form a web of randomly disbursed meltblown fibers. Such a process is disclosed, for example, in U. S. Pat. No. 3, 849,241 to Butin. Meltblown fibers are microfibers which may be continuous or discontinuous and are generally smaller than 10 microns in diameter.

As used herein the term “meltspun” includes “spunbond” or “meltblown”, and may or may not include bonding.

As used herein the term “bonded carded web” refers to a nonwoven web formed by carding processes as are known to those skilled in the art and further described, for example, in US Patent No. 4, 488, 982, which is incorporated herein by reference to the extent it is consistent with the present invention. In the carding process, one may use a blend of staple fibers, bonding fibers, and possibly other bonding components, such as adhesive. These components are formed into a bulky ball that is combed or otherwise treated to create a substantially uniform basis weight. This web is heated or otherwise treated to activate any adhesive component, resulting in an integrated, lofty nonwoven material.

As used herein the term “creping” refers to when a polymer that is adhered to a web is scraped off of a dryer surface (e.g. a Yankee dryer surface) with a doctor blade. For example, a frothed composition may be applied to a heated dryer that evaporates water from the frothed composition. The heat of the dryer changes the frothed composition into a polymer film. Using compression force, the web contacts the film on the surface of the dryer so that it adheres thereto prior to being creped.

As used herein the term “froth” is a liquid foam. When a frothable composition is heated, it will not form a solid foam structure. Instead, when applied to a heated surface, the frothable composition turns into a substantially continuous film.

As used herein, the terms “comprises”, “comprising”, and other derivates from the root term “comprise” are intended to be open-ended terms that specify the presence of any stated features, elements, integers, steps, or components, and are not intended to preclude the presence or addition of one or more other features, elements, integers, steps, components, or groups thereof.

It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only, and is not intended as limiting the broader aspects of the present invention.

DETAILED DESCRIPTIONOF THE INVENTION

The present invention provides for a nonwoven web composite which contains fibers containing regenerated cellulose and short fibers hydroentangled with the fibers containing regenerated cellulose.

In one embodiment of the present invention, the nonwoven composite web of the present invention is prepared from a nonwoven web of continuous fibers containing regenerated cellulose, and a layer of discontinuous fibers which are hydroentangled with the nonwoven web of continuous fibers containing regenerated cellulose to form a nonwoven composite. Alternatively, the nonwoven composite web of the present invention may be prepared from a nonwoven web of discontinuous fiber containing regenerated cellulose, and a layer of other discontinuous fibers which are hydroentangled with the nonwoven web of discontinuous fibers containing regenerated cellulose to form a nonwoven composite.

Regenerated cellulose fibers are well known in the art. There are many processes available for production of regenerated cellulose fibers. For example, viscose rayon is a regenerated cellulose fiber produced by a process that includes a step of steeping cellulose in a mercerizing strength caustic soda solution to form an alkali cellulose. As another example, cuprammonium rayon is a regenerated cellulose fiber produced by a process that includes a step of dissolving cellulose in a solution of ammoniacal copper oxide. As a further example, Lyocell is a term used for a regenerated cellulose fiber composed of cellulose precipitated from an organic solution in which no substitution of hydroxyl groups takes place and no chemical intermediates are formed. Lyocell may be produced by a process that includes dissolving cellulose in N-methylmorpholine-N-oxide and water, suitably about 12% water. In one embodiment, the regenerated cellulose fibers of the nonwoven composite web may be selected from the group consisting of viscose rayon, cuprammonium rayon, and lyocell. In a further embodiment, the regenerated cellulose fibers of the nonwoven composite web may by lyocell fibers. In some embodiments, the regenerated cellulose fibers may have deniers ranging from about 0.1 to about 2.7 denier per fiber and heavier, or suitably ranging from about 0.9 to about 2.7 denier per fiber. Lyocell fibers, methods of making lyocell fibers, and methods of making webs of lyocell fibers are further described in U.S. patent 6,306,334 to Luo et al., U.S. patent 7,067,444 to Luo et al., and U.S. patent 8,012,565 to Luo, the contents of which are incorporated herein by reference.

In one embodiment, the regenerated cellulose fibers may be a nonwoven web of fibers formed from lyocell regenerated cellulose. For example, the regenerated cellulose fibers may be a TencelWeb nonwoven web of fibers formed from lyocell regenerated cellulose (available from Lenzing AG located in Lenzing, Austria.

The nonwoven web of continuous fiber containing regenerated cellulose may be formed by known nonwoven extrusion processes, such as, for example, known solvent spinning or melt-spinning processes, for example, spunbonding or meltblowing.

The regenerated cellulose fibers may be prepared from virgin regenerated cellulose, recycled regenerated cellulose, or a mixture thereof.

The regenerated cellulose fibers may further include other solvent-spinnable or melt-spinnable thermoplastic polymers, co-polymers or blends thereof. Suitable other polymers include, but are not limited to, polyolefins, such as, for example, polypropylene, polyethylene, and so forth, polyamides, polyesters, polyurethanes, thermoplastic elastomers, blends and copolymers thereof, and so forth. Optionally, the regenerated cellulose fibers may be multicomponent fibers consisting of two or more different polymers. The regenerated cellulose fibers may be round or any suitable shape known to those skilled in the art, including but not limited to, bilobal, trilobal, and so forth. Desirably, the regenerated cellulose fibers may have a basis weight from about 8 to about 70 gsm. More desirably, the regenerated cellulose fibers have a basis weight from about 10 to about 35 gsm.

Other components or additives may be added to the regenerated cellulose used to prepare the regenerated cellulose fibers including, for example, pigments, antioxidants, flow promoters, stabilizers, fragrances, abrasive particles, filler, and the like.

The discontinuous fibers which are hydroentangled with the nonwoven web of regenerated cellulose fibers may be staple fibers, pulp fibers, or blends thereof. The discontinuous fibers may be formed into a web and entangled with the nonwoven web of regenerated cellulose fibers or the discontinuous fibers may be laid upon the nonwoven web of regenerated cellulose fibers and then entangled with the nonwoven web of regenerated cellulose fibers.

Generally, the discontinuous fibers are staple fibers or pulp fibers. Staple fibers and pulp fibers often have a fiber length in the range of from about 1 to about 150 millimeters, in some embodiments from about 5 to about 50 millimeters, in some embodiments from about 10 to about 40 millimeters, and in some embodiments, from about 10 to about 25 millimeters. Generally, staple fibers are carded using a conventional carding process, e.g., a woolen or cotton carding process. Other processes, however, such as air laid or wet laid processes, may also be used to form the staple fiber or pulp fiber web. A wide variety of polymeric materials are known to be suitable for use in fabricating staple fibers. Examples include, but are not limited to, polyolefins, polyesters, polyamides, regenerated cellulose, as well as other melt-spinnable and/or fiber forming polymers. Any convention polymers typically used to produce fibers may be used as the polymeric component to produce the staple fibers usable in the present invention. Other suitable staple fibers include, but are not limited to, acetate staple fibers, rayon staple fibers, Nomex® staple fibers, Kevlar® staple fibers, polyvinyl alcohol staple fibers, lyocell staple fibers, and so forth.

The staple fibers useable to produce the nonwoven composite may also be multicomponent (e.g., bicomponent) staple fibers. For example, suitable configurations for the multicomponent fibers include side-by-side configurations and sheath-core configurations, and suitable sheath-core configurations include eccentric sheath-core and concentric sheath-core configurations. In some embodiments, as is well known in the art, the polymers used to form the multicomponent fibers have sufficiently different melting points to form different crystallization and/or solidification properties. The multicomponent fibers may have from about 20% to about 80%, and in some embodiments, from about 40% to about 60% by weight of the low melting polymer. Further, the multicomponent fibers may have from about 80% to about 20%, and in some embodiments, from about 60% to about 40%, by weight of the high melting polymer. When bicomponent or multicomponent fibers are used as the staple fiber or are a portion of the staple fibers, the composite may be further bonded by using heat.

In a further aspect of the invention, the nonwoven web composite may also contain various materials such as, for example, activated charcoal, clays, starches, and superabsorbent materials. For example, these materials may be added to the non-thermoplastic absorbent staple fibers prior to their incorporation into the composite layer. Alternatively and/or additionally, these materials may be added to the composite after the non-thermoplastic absorbent staple fibers and thermoplastic fibers are combined. Useful superabsorbents are known to those skilled in the art of absorbent materials.

The hydroentangling of the staple of pulp fibers into the nonwoven web of regenerated cellulose fibers may be accomplished utilizing conventional hydroentangling equipment well known in the art. Such hydroentangling equipment can be obtained from Fleissner GmbH of Egelsbach, Germany, or other well known manufacturers. The hydroentangling of the present invention may be carried out with any appropriate working fluid such as, for example, water. The working fluid flows through a manifold which evenly distributes the fluid to a series of individual holes or orifices. These holes or orifices may be from about 0.003 to about 0.015 inch in diameter. For example, the invention may be practiced utilizing a manifold containing a strip having 0.007 inch diameter orifices, 30 holes per inch, and 1 row of holes. Many other manifold configurations and combinations may be used. For example, a single manifold may be used or several injectors may be arranged in succession.

In the hydroentangling process, the working fluid passes through the orifices at a pressures ranging from about 200 to about 3500 pounds per square inch gage (psig). At the upper ranges of the described pressures it is contemplated that the material or materials to be hydroentangled may be processed at speeds of about 500 feet per minute (fpm) to about 2000 fpm. The fluid impacts the material which are supported by a foraminous surface or wire which may be, for example, a single plane mesh having a mesh size of from about 40 times 40 to about 100 times 100. The foraminous surface may also be a multi-ply mesh having a mesh size from about 50 times 50 to about 200 times 200. As is typical in many water jet treatment processes, vacuum slots may be located directly beneath the hydroentangling injectors and/or beneath the foraminous entangling surface downstream of the hydroentangling manifold so that excess water is withdrawn from the hydroentangled material or materials.

It may be desirable to use finishing steps and/or post treatment processes to impart selected properties to the nonwoven web composite. For example, the nonwoven web composite may be subjected to mechanical treatments, chemical treatments, and so forth. Mechanical treatments include, by way of non-limiting example, pressing, creping, brushing, and/or pressing with calender rolls, embossing rolls, and so forth to provide a uniform exterior appearance and/or certain tactile properties. Chemical post-treatments include, by way of non-limiting example, treatment with adhesives, dyes, and so forth.

In creping the nonwoven web composite, an aqueous dispersion of creping chemicals may be sprayed onto a dryer surface. For example, a liquid or a frothed chemistry may be used. In contrast to the liquid chemistry, the frothed chemistry has enough structural integrity to reach the dryer surface. By creating a frothed chemistry, a chemistry applicator can be placed in much closer proximity to the dryer surface. The close proximity of the chemistry applicator to the dryer surface improves chemical mass efficiency and energy efficiency. Efficiency is increased because the air introduced into the froth acts as a diluter. As a result, less heat is required to remove water from the creping chemistry during the drying process.

In general, preparing frothed chemicals utilizes a system that pumps both liquid and air into a mixer. The mixer blends the air into the liquid to produce a froth which inherently includes a plurality of small air bubbles. The froth exits the mixer and flows to an applicator.

One parameter to define the quality of frothed chemistry is the blow ratio, which is defined by ratio of volume of small air bubbles entrapped by dispersion chemical to the volume of the dispersion before mixing. For example, at a blow ratio of 10:1, a dispersion flow rate of 1 liter/minute will be able to entrap 10 liters/minute of air into its liquid and produce a total froth flow rate of 11 liters per minute.

To achieve a high blow ratio, both the mechanical mixing and the frothing capability of the additive composition are determining factors. If a chemical can only hold or entrap air volume up to a blow ratio of 5, no matter how powerful a froth unit is, it won’t be able to produce a stable froth having a blow ratio of 10. Any extra air beyond the blow ratio of 5 will release out of the froth system once the mechanical force is removed. In other words, any entrapped air higher than the dispersion’s air containment capability will become instable. Most of such instable air bubbles will escape from the froth (debubbling) immediately after mechanical agitation is stopped.

An additional advantage of the froth creping is that after the creping step, the dry layer of additive composition remaining on the tissue substrate surface adds more bulk. This increase in bulk is due to the entrapped air inside the coated layer. Though the frothed additive composition becomes a film during the drying step, not all of the air entrapped in the froth is lost during the drying step due to the higher viscosity associated with the higher solid-levels in the frothed additive composition. In some embodiments, the film may be a substantially continuous film.

Most commercial foaming agents are suitable for creating the creping froth. Suitable foaming agents include polymeric materials in liquid form. Frothable compositions of water insoluble polymers may be in the form of dispersions or solutions. Examples of frothable dispersions include, but are not limited to, a polyolefin dispersion such as HYPOD 8510, commercially available from The Dow Chemical Compoany, Freeport, Texas, U.S.A.; and a polyisoprene dispersion, such as those sold under the KRATON brand, commercially available from Kraton Polymers U.S. LLC, Houston, Texas, U.S.A., polybutadiene-styrene block copolymer dispersion, latex dispersion such as E-PLUS, commercially available from Wacker, Munich, Germany; polyvinyl pyrrolidone-styrene copolymer dispersion and polyvinyl alcohol-ethylene copolymer dispersion, both available from Aldrich, Milwaukee, Wisconsin, U.S.A.

Additional details regarding the froth creping process may be found in U.S. Patent Application Serial Number 12/979852 filed December 28, 2010, the entirety of which is incorporated by reference herein.

Importantly, efficiency of creping of the nonwoven composite comprising regenerated cellulose fibers is improved by the fact that the regenerated cellulose fibers are not as temperature sensitive as other synthetic thermoplastic polymer fibers. Nonwoven composites comprising regenerated cellulose fibers may be dried on a hot dryer surface at a temperature exceeding about 300 degrees Fahrenheit, suitably at a temperature ranging from 350 degrees to about 550 degrees Fahrenheit, and more suitably at a temperature ranging from about 550 degrees to about 550 degrees Fahrenheit.

To gain a better understanding of the present invention, attention is directed to the Figure of the present specification. Referring to FIG. 1, there is schematically illustrated a process 10 for forming a nonwoven composite of the present invention. As is stated above, the nonwoven composite of the present invention may consist of all regenerated cellulose fibers, or only comprise regenerated cellulose materials in part. For example, continuous fibers and/or discontinuous fibers may consist of all regenerated cellulose material, or comprise only in part regenerated cellulose material.

According to the present invention, a dilute suspension of discontinuous fibers is supplied by a head-box 12 and deposited via a sluice 14 in a uniform dispersion onto a forming fabric 16 of a conventional papermaking machine. The suspension of fibers may be diluted to any desired consistency. For example, the suspension may contain from about 0.01 to about 1.5 percent by weight fibers suspended in water. Water is removed from the suspension of fibers to form a layer of discontinuous fibers 18.

Small amounts of wet-strength resins and/or resin binders may be added to improve strength and abrasion resistance. Useful binders and wet-strength resins include, for example, Kymene 557 H available from the Ashland Hercules Chemical Company. Cross-linking agents and/or hydrating agents may also be added to the fiber mixture. Debonding agents may be added to the fiber mixture to reduce the degree of any potential hydrogen bonding if a very open or loose nonwoven fiber web is desired. One exemplary debonding agent is available from the Quaker Chemical Company, Conshohocken, Pennsylvania, under the trade designation Quaker 2008. The addition of certain debonding agents in the amount of, for example, 0.1 to 4 percent, by weight, of the composite also appears to reduce the measured static and dynamic coefficients of friction and improve the abrasion resistance of the continuous filament rich side of the nonwoven composite. The de-bonder is believed to act as a lubricant or friction reducer.

A nonwoven web 20 comprising regenerated cellulose fibers is unwound from a supply roll 22, and passes through a nip 24 of an S-roll arrangement 26 formed by the stack rollers 28 and 30. The nonwoven web 20 may be formed by known nonwoven web manufacturing processes, such as, for example, known solvent spinning or melt-spinning processes, and passed directly through the nip 24 without first being stored on a supply roll. The continuous filament nonwoven web 20 can be a nonwoven web of continuous melt-spun regenerated cellulose filaments formed by the spunbond process. The melt-spun filaments may be formed from any composition including regenerated cellulose which is described above.

The nonwoven substrate 20 may have a basis weight from about 3.5 to about 70 grams per square meter (gsm). More particularly, the nonwoven substrate 20 may have a basis weight from about 10 to about 35 gsm. The polymers may include additional materials such as, for example, pigments, antioxidants, flow promoters, stabilizers and the like.

Desirably the nonwoven continuous filament web 20 has a total bond area of less than about 30 percent and a uniform bond density greater than about 100 bonds per square inch. For example, the nonwoven continuous filament web may have a total bond area from about 2 to about 30 percent (as determined by conventional optical microscopic methods) and a bond density from about 250 to about 600 pin bonds per square inch.

Such a combination of total bond area and bond density may be achieved by bonding the continuous filament web with a pin bond pattern having more than about 100 pin bonds per square inch which provides a total bond surface area less than about 30 percent when fully contacting a smooth anvil roll. The upper limit of bonds per square inch could be 600 pin bonds, or more, per square inch. As the number of pin bonds per square inch increases, the size of the pins will generally decrease in order to maintain the bond density within a desired range. Desirably, the bond pattern may have a pin bond density from about 250 to about 350 pin bonds per square inch and a total bond surface area from about 10 percent to about 25 percent when contacting a smooth anvil roll.

Although pin bonding produced by thermal bond rolls is described above, the present invention contemplates any form of bonding which produces good tie down of the filaments with minimum overall bond area, such as a hot air knife (HAK). Another example is a combination of thermal bonding and latex impregnation that may be used to provide desirable filament tie down with minimum bond area. Alternatively and/or additionally, a resin, latex or adhesive may be applied to the nonwoven web by, for example, spraying or printing, and dried to provide the desired bonding.

The layer of fibers 18 are then laid on the nonwoven web 20 which rests upon a foraminous entangling surface 32 of a conventional hydraulic entangling machine. It is preferable that the fibers 18 are between the nonwoven web 20 of regenerated cellulose and the hydraulic entangling manifolds 34. The layer of fibers 18 and nonwoven web 20 pass under one or more hydraulic entangling manifolds 34 and are treated with jets of fluid to entangle all, or at least a major portion, of the fibers with the filaments of the nonwoven web 20 of regenerated cellulose. The jets of fluid also drive fibers into and through the nonwoven web of regenerated cellulose fibers 20 to form the composite 36.

Alternatively, hydraulic entangling may take place while the layer of fibers 18 and nonwoven web 20 are on the same foraminous screen (i.e., mesh nonwoven composite) on which the wet-laying took place. The present invention also contemplates superposing a dried sheet on a nonwoven web containing regenerated cellulose fibers, rehydrating the dried sheet to a specified consistency and then subjecting the rehydrated sheet to hydraulic entangling.

The hydraulic entangling may take place while the fibers 18 are highly saturated with water. For example, the layer of fibers 18 may contain up to about 90 percent by weight water just before hydraulic entangling. Alternatively, the fibers may be an air-laid or dry-laid layer of fibers.

The hydraulic entangling may be accomplished utilizing conventional hydraulic entangling equipment such as may be found in, for example, in U. S. Pat. No. 3,485,706 to Evans, the disclosure of which is hereby incorporated herein by reference. The hydraulic entangling of the present invention may be carried out with any appropriate working fluid such as, for example, water. The working fluid flows through a manifold which evenly distributes the fluid to a series of individual holes or orifices. These holes or orifices may be from about 0.003 to about 0.015 inch in diameter. For example, the invention may be practiced utilizing a manifold produced by Rieter-PerfoJet, Inc. of Grenoble, France. Many other manifold configurations and combinations may be used. For example, a single manifold may be used or several manifolds may be arranged in succession.

In the hydraulic entangling process, the working fluid passes through the orifices at a pressures ranging from about 200 to about 3000 pounds per square inch gauge (psig). At the upper ranges of the described pressures it is contemplated that the nonwoven composites may be processed at speeds of about 1500 feet per minute (fpm). The fluid impacts the fibers 18 and the nonwoven web 20 of regenerated cellulose fibers which are supported by a foraminous surface which may be, for example, a single plane mesh having a mesh size of from about 8×8 to about 100×100. The foraminous surface may also be a multi-ply mesh having a mesh size from about 50×50 to about 200×200. As is typical in many water jet treatment processes, vacuum slots 38 may be located directly beneath the hydro-needling manifolds or beneath the foraminous entangling surface 32 downstream of the entangling manifold so that excess water is withdrawn from the hydraulically entangled composite 36.

Although the inventors should not be held to a particular theory of operation, it is believed that the columnar jets of working fluid which directly impact fibers laying on the nonwoven web of regenerated cellulose fibers work to drive those fibers into and partially through the matrix or nonwoven network of filaments in the web. When the fluid jets and fibers interact with a nonwoven web having the above-described bond characteristics (and a filament diameter in the range of from about 5 microns to about 40 microns) the fibers are also entangled with regenerated cellulose filaments of the nonwoven web and with each other. On the other hand, if the total bond area of the web is too great, the fiber penetration may be poor. Moreover, too much bond area will also cause a splotchy nonwoven composite because the jets of fluid will splatter, splash and wash off fibers when they hit the large non-porous bond spots. The specified levels of bonding provide a coherent web which may be formed into a nonwoven composite by hydraulic entangling on only one side and still provide a strong, useful nonwoven composite as well as a nonwoven composite having desirable dimensional stability.

In one aspect of the invention, the energy of the fluid jets that impact the fibers and web may be adjusted so that the fibers are inserted into and entangled with the web of regenerated cellulose fibers in a manner that enhances the two-sidedness of the nonwoven composite. That is, the entangling may be adjusted to produce high fiber concentration on one side of the nonwoven composite and a corresponding low fiber concentration on the opposite side. Alternatively, the nonwoven web of regenerated cellulose fibers may be entangled with a fiber layer on one side and a different fiber layer on the other side.

After the fluid jet treatment, the nonwoven composite 36 may be transferred to a non-compressive drying operation. A differential speed pickup roll 40 may be used to transfer the material from the hydraulic needling belt to a non-compressive drying operation. Alternatively, conventional vacuum-type pickups and transfer nonwoven composites may be used. If desired, the nonwoven composite may be wet-creped by liquid or frothed creping process as described above before being transferred to the drying operation. Non-compressive drying of the web may be accomplished utilizing a conventional rotary drum through-air drying apparatus shown in FIG. 1 at 42. The through-dryer 42 may be an outer rotatable cylinder 44 with perforations 46 in combination with an outer hood 48 for receiving hot air blown through the perforations 46. A through-dryer belt 50 carries the nonwoven composite 36 over the upper portion of the through-dryer outer cylinder 40. The heated air forced through the perforations 46 in the outer cylinder 44 of the through-dryer 42 removes water from the nonwoven composite 36. The temperature of the air forced through the nonwoven composite 36 by the through-dryer 42 may range from about 200 to about 550 degrees Fahrenheit, suitably from about 300 to about 550 degrees Fahrenheit, and more suitably from about 500 to about 550 degrees Fahrenheit. Other useful through-drying methods and apparatus may be found in, for example, U.S. Pat. Nos. 2,666,369 and 3,821,068, the contents of which are incorporated herein by reference.

It may be desirable to use finishing steps and/or post treatment processes to impart selected properties to the composite 36. For example, the nonwoven composite may be lightly pressed by calendar rolls, creped or brushed to provide a uniform exterior appearance and/or certain tactile properties. Alternatively and/or additionally, chemical post-treatments such as, adhesives or dyes may be added to the nonwoven composite.

TEST PROCEDURES

Caliper: The caliper of a fabric corresponds to its thickness. The caliper was measured in the example in accordance with TAPPI test methods T402 “Standard Conditioning and Testing Atmosphere For Paper, Board, Pulp Handsheets and Related Products” or T411 om-89 “Thickness (caliper) of Paper, Paperboard, and Combined Board” with Note 3 for stacked sheets. The micrometer used for carrying out T411 om-89 may be an Emveco Model 200A Electronic Microgage (made by Emveco, Inc. of Newberry, Oreg.) having an anvil diameter of 57.2 millimeters and an anvil pressure of 2 kilopascals.

Grab Tensile Strength: The grab tensile test is a measure of breaking strength of a fabric when subjected to unidirectional stress. This test is known in the art and conforms to the specifications of Method 5100 of the Federal Test Methods Standard 191A. The results are expressed in pounds to break. Higher numbers indicate a stronger fabric. The grab tensile test uses two clamps, each having two jaws with each jaw having a facing in contact with the sample. The clamps hold the material in the same plane, usually vertically, separated by 3 inches (76 mm) and move apart at a specified rate of extension. Values for grab tensile strength are obtained using a sample size of 4 inches (102 mm) by 6 inches (152 mm), with a jaw facing size of 1 inch (25 mm) by 1 inch, and a constant rate of extension of 300 mm/min. The sample is wider than the clamp jaws to give results representative of effective strength of fibers in the clamped width combined with additional strength contributed by adjacent fibers in the fabric. The specimen is clamped in, for example, a Sintech 2 tester, available from the Sintech Corporation of Cary, N.C., an Instron Model™, available from the Instron

Corporation of Canton, Mass., or a Thwing-Albert Model INTELLECT II available from the Thwing-Albert Instrument Co. of Philadelphia, Pa. This closely simulates fabric stress conditions in actual use. Results are reported as an average of three specimens and may be performed with the specimen in the cross direction (CD) or the machine direction (MD).

Absorption Capacity: The absorption capacity refers to the capacity of a material to absorb a liquid (e.g., water or motor oil) over a period of time and is related to the total amount of liquid held by the material at its point of saturation. The absorption capacity is measured in accordance with Federal Specification No. UU-T595C on industrial and institutional towels and wiping papers. Specifically, absorption capacity is determined by measuring the increase in the weight of the sample resulting from the absorption of a liquid and is expressed as either the weight of liquid absorbed or the % liquid absorbed, using the following equations:

Absorption Capacity=(saturated sample weight-sample weight).

or

% Absorption Capacity=[(saturated sample weight-sample weight)/sample weight]×100.

Cup Crush: The softness of a nonwoven fabric may be measured according to the "cup crush" test. The cup test evaluates fabric stiffness by measuring the peak load required for a 4.5 cm diameter hemispherically shaped foot to crush a 23 cm by 23 cm piece of fabric shaped into an approximately 6. 5 cm diameter by 6. 5 cm tall inverted cup while the cup shaped fabric is surrounded by an approximately 6.5 cm diameter cylinder to maintain a uniform deformation of the cup shaped fabric. An average of 10 readings is used. The foot and the cup are aligned to avoid contact between the cup walls and the foot which could affect the readings. The peak load is measured while the foot is descending at a rate of about 0.25 inches per second (38 cm per minute) and is measured in grams. A lower cup crush value indicates a softer laminate. The cup crush test also yields a value for the total energy required to crush a sample (the "cup crush energy") which is the energy from the start of the test to the peak load point, i.e. the area under the curve formed by the load in grams on one axis and the distance the foot travels in millimeters on the other. Cup crush energy is reported in gf*mm. A suitable device for measuring cup crush is a model FTD-G500 load cell (500 gm range) available from the Schaevitz Company, Pennsauken, N.J.

In-Hand Ranking Test (IHR): IHR is a basic assessment of in-hand feel of fibrous webs and assesses attributes such as softness. This test is useful in obtaining a quick read as to whether a process change is humanly detectable and/or affects the softness perception, as compared to a control. The difference of the IHR softness data between a treated web and a control web reflects the degree of softness improvement.

A panel of testers was trained to provide assessments more accurately than an average untrained consumer might provide. Rank data generated for each sample code by the panel were analyzed using a proportional hazards regression model. This model computationally assumes that the panelist proceeds through the ranking procedure from most of the attribute being assessed to least of the attribute. The softness test results are presented as log odds values. The log odds are the natural logarithm of the risk ratios that are estimated for each code from the proportional hazards regression model. Larger log odds indicate the attribute of interest is perceived with greater intensity.

Because the IHR results are expressed in log odds, the difference in improved softness is actually much more significant than the data indicates. For example, when the difference of IHR data is 1, it actually represents 10 times (101 = 10) improvement in overall softness, or 1,000% improvement over its control. In another example, if the difference is 0.2, it represents 1.58 times (100.2 = 1.58) or a 58% improvement.

The data from the IHR can also be presented in rank format. The data can generally be used to make relative comparisons within tests as a product's ranking is dependent upon the products with which it is ranked. Across-test comparisons can be made when at least one product is tested in both tests.

The following examples and comparative examples were prepared to demonstrate the unexpected properties of the nonwoven composite of the present invention.

EXAMPLES

Coating chemistries as described below were frothed and applied onto the drum of a heated cylinder in an offline converting process. The dryer had a diameter of 22 inches. Various dry hydro-entangled basesheets were coated on the heated cylinder roll with the coating chemistries and creped off the heated roll upon curing of the froth coating on the substrate.

The various basesheets evaluated were:

1. Commercial 54 gsm Pulp/Polyropylene (PP) commercial Hydroknit® basesheet.
2. Lyocell Bonded Carded Web hydroentangled with pulp (Lyocell Hydroknit ®) (Lyocell basis weight = 25 gsm)
3. TencelWeb hydroentangled with pulp (TencelWeb Hydroknit ®) (TencelWeb basis weight = 15 gsm)

The above basesheets were treated with following chemistries:

1. Blend of 14% Solids Crepetrol :Resozol (90:10) (available from Ashland, Inc. located in Wilmington, Delaware)+ Foaming agent. (Unifroth 0154 (available from from Unichem, Inc. located in Greenville, SC)
2. HYPOD 8510 creping chemistry with 30% DPOD solids + 10% Expancel® (available from Eka Chemicals, Inc. located in Duluth, GA.

The chemistries were diluted to the above levels using water and froth foamed using the froth generating process as described above. (

Process details are listed in Table 1.

Table 1: Processing conditions used for each example code.

Code	Substrate	Chemistry	Foam Unit Settings			Process Parameter	
			Flow rate (cc/min)	Mixing (%)	Blow Ratio	Dryer Temp (deg F)	Machine Speed (ft/min)
1	Control Uncreped TencelWeb						
2	Control Uncreped Lyocell (70 gsm)						
3	Control Uncreped Lyocell (80 gsm)						
423	PP Spunbond hydroknit®	14% Solids Crepetrol:Resozol (90:10) + Foaming agent	50	25	35	250	50
424	Lyocell hydroknit®	14% Solids Crepetrol:Resozol (90:10) + Foaming agent	50	25	35	250	50
717	TencelWeb hydroknit®	14% Solids Crepetrol:Resozol (90:10) + Foaming agent	50	25	35	250	50
511	PP Spunbond hydroknit®	30% HYPOD 8510 solids + 10% Expancel®	100	40	13	280	50
714	Creped Lyocell hydroknit®(70 gsm)	30% HYPOD 8510 solids + 10% Expancel®	100	40	13	280	50
715	Creped Lyocell hydroknit®(80 gsm)	30% HYPOD 8510 solids + 10% Expancel®	100	40	13	280	50
512s	TencelWeb hydroknit®	30% HYPOD 8510 solids + 10% Expancel®	100	40	13	280	50
HYPOD 8510 is available as 42% solids, Foaming agent used for Unifroth 0154 from Unichem							

Tables 2, 3, 4 and 5 summarize the measured properties for each example code.

Table 2 contains the material bulk and caliper data. The data shows that creping increases the bulk of the materials when compared to their corresponding control.

Table 3 contains the absorbent capacity data which shows that creping combined with using Lyocell fibers results in increased absorbent capacity compared to standard pulp/PP hydroentangled materials (Code 512s compared to Code 511).

Table 4 contains the cup-crush data for the various material examples. The data shows that Lyocell or TencelWeb when hydroentangled with pulp and creped results in lower energy which means it is a softer feeling material. The decrease in energy is as high as 66% (between Code 3 and Code 512s).

Table 5 contains the IHR (in-hand ranking) softness data for select codes which shows that TencelWeb hydroentangled pulp is perceived to be softer then polypropylene spunbond hydroentangled with pulp (Code 512s and 511)

Table 2: Basis Weight, Caliper, and Density

	Basis Weight (gsm)	Thickness (mm)	Density (g/m3)
Code	Basis Weight (gsm)	Thickness (mm)	Density (g/m3)
1	79.44	0.50	0.16
2	78.47	0.46	0.17
3	82.97	0.48	0.17
423	73.06	0.65	0.11
424	75.49	0.84	0.09
717	85.82	0.52	0.17
511	65.41	0.66	0.10
714	90.00	0.66	0.14
715	93.76	0.58	0.16
512s	84.00	0.48	0.18

Table 3: Absorbent Capacity (Water)

Code	Specific Capacity (g/g)
	5.06
	5.20
	5.12
423	3.79
424	7.54
717	5.04
511	3.85
714	5.82
715	5.58
512s	6.22

Table 4: Cup-Crush Data

	Average		Std.Dev	
Code	Total Energy (gf*mm)	Peak Load (gf)	Total Energy (gf*mm)	Peak Load (gf)
1	8481.69	1373.26	472.09	75.61
2	8335.30	538.80	459.44	6.51
3	10055.71	381.26	580.00	106.75
423	2260.52	140.75	344.00	18.12
424	1609.43	107.39	423.54	22.41
717	5128.57	531.91	326.91	27.67
511	2890.72	171.28	124.16	11.69
714	3821.89	435.70	262.22	10.15
715	5585.32	327.80	380.47	13.34
512s	3381.10	221.06	221.61	17.41

Table 5: IHR softness ranking

Code Number	SOFTNESS RANKING		DRAPE-ABILITY RANKING	
423	-5.1881	D	0.1	A
424	-2.4161	B	0.5872	A
511	-3.6544	C	-1.0072	B
512s	0	A	0	A

Although the present invention has been described with reference to various embodiments, those skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention. As such, it is intended that the foregoing detailed description be regarded as illustrative rather than limiting and that it is the appended claims, including all equivalents thereof, which are intended to define the scope of the invention.

WHAT IS CLAIMED IS:

1. A direct-formed nonwoven comprising regenerated cellulose fibers and staple or wood pulp fibers, the nonwoven being formed by the steps of:
placing the regenerated cellulose fibers on a forming surface;
depositing the staple or wood pulp fibers on the regenerated cellulose fibers;
hydroentangling the regenerated cellulose fibers and the staple or wood pulp fibers together to form a hydroentangled composite;
drying the hydroentangled composite; then,
creping the hydroentangled composite with a frothed creping solution or dispersion.

2. The direct-formed nonwoven of claim 1 wherein the regenerated cellulose fibers have a basis weight from about 10 to about 20 grams per square meter.

3. The direct-formed nonwoven of claim 1 wherein the regenerated cellulose fibers are continuous fibers.

4. The direct-formed nonwoven of claim 1 wherein the staple or wood pulp fibers have a basis weight from about 30 to about 150 grams per square meter.

5. The direct-formed nonwoven of claim 1 wherein the creping step includes the steps of:
positioning an additive composition applicator adjacent to a hot non-permeable dryer surface;
applying the frothed dispersion or frothed solution comprising an additive composition to the dryer surface;
allowing the frothed dispersion or frothed solution to convert to an adhesive film;
directly bonding the hydroentangled composite to the adhesive film; and
scraping the bonded hydroentangled composite and adhesive film from the dryer surface.

6. The direct-formed nonwoven of claim 5 wherein the additive composition further comprises a foaming agent.

7. The direct-formed nonwoven of claim 6 wherein the additive composition comprises a hydroxypropyl cellulose solution.

8. The direct-formed nonwoven of claim 5 wherein the hot non-permeable dryer surface has a temperature exceeding about 300 degrees Fahrenheit, optionally between about 500 and about 550 degrees Fahrenheit.

9. An integrated composite fabric comprising greater than about 5 weight percent and less than about 30 weight percent continuous regenerated cellulose filaments and greater than about 70 weight percent and less than about 95 weight percent wood pulp fibers.

10. The integrated composite fabric of claim 9 having an absorbent capacity of greater than 5.6 g/g.

11. The integrated composite fabric of claim 9 having a softness of 4 logs or better than a similar integrated composite fabric with polypropylene filaments instead of regenerated cellulose filaments.

12. The integrated composite fabric of claim 9 wherein the wood pulp fibers are discontinuous fibers.

13. The integrated composite fabric of claim 9 wherein the continuous regenerated cellulose filaments are Lyocell filaments.

14. The integrated composite fabric of claim 9 where in the continuous regenerated cellulose filaments are spunbond filaments.

15. A method of making a direct-formed nonwoven comprising regenerated cellulose fibers and wood pulp fibers, the method comprising the steps of:
placing the regenerated cellulose fibers on a forming surface;
depositing the wood pulp fibers on the regenerated cellulose fibers;
hydroentangling the regenerated cellulose fibers and the wood pulp fibers together to form a hydroentangled composite;

drying the hydroentangled composite; then,
creping the hydroentangled composite with a frothed creping solution or dispersion.

16. The method of claim 15 wherein the regenerated cellulose fibers are continuous fibers.

17. The method of claim 15 wherein the creping step includes the steps of:
positioning an additive composition applicator adjacent to a hot non-permeable dryer surface;
applying the frothed dispersion or frothed solution comprising an additive composition to the dryer surface;
allowing the frothed dispersion or frothed solution to convert to an adhesive film;
directly bonding the hydroentangled composite to the adhesive film; and
scraping the bonded hydroentangled composite and adhesive film from the dryer surface.

18. The method of claim 17 wherein the additive composition further comprises a foaming agent.

19. The method of claim 18 wherein the additive composition comprises a hydroxypropyl cellulose solution.

20. The method of claim 17 wherein the hot non-permeable dryer surface has a temperature exceeding about 300 degrees Fahrenheit, optionally between about 500 and about 550 degrees Fahrenheit.

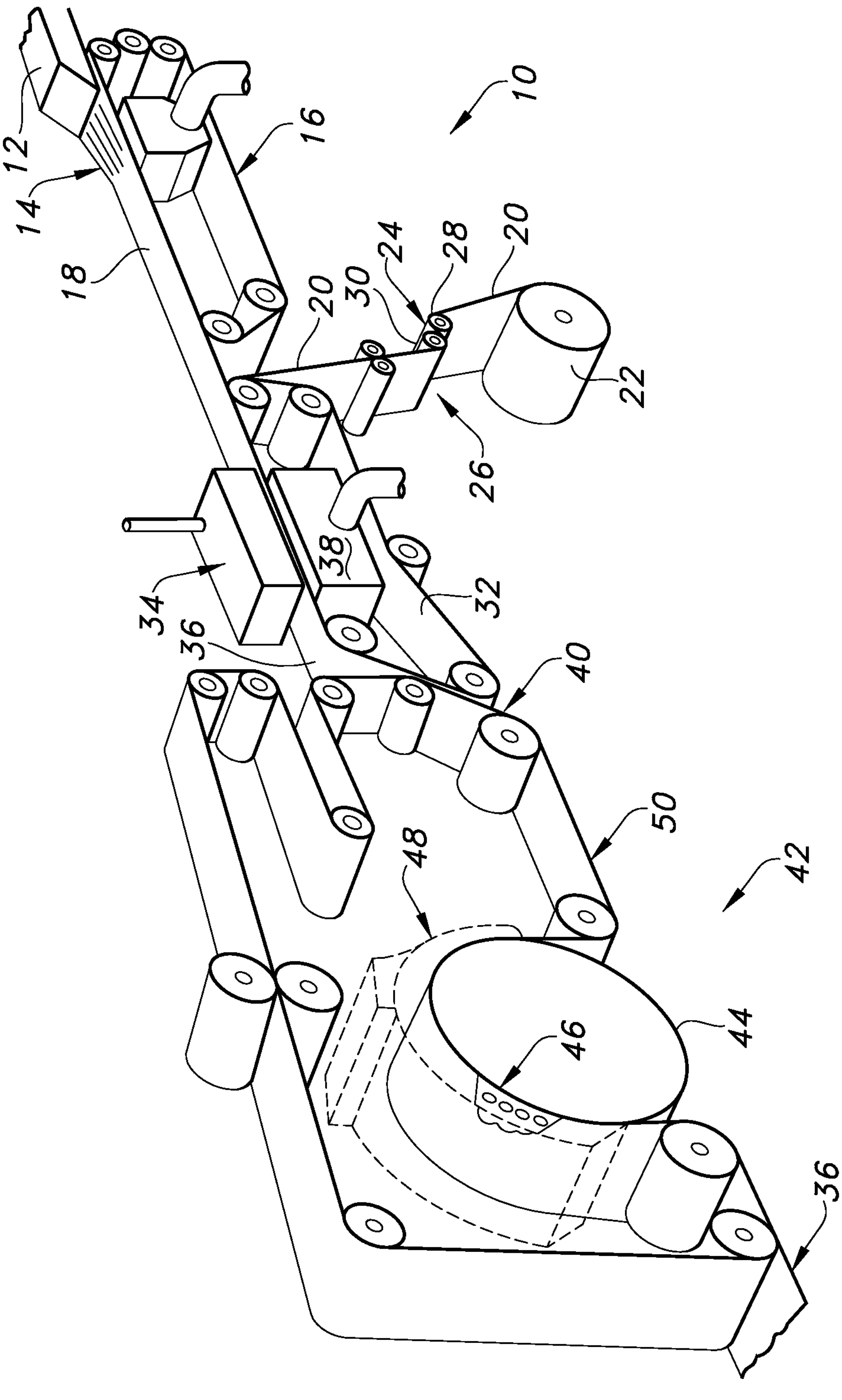

FIG. 1