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(54) **Title**: FIBROUS STRUCTURES AND METHODS FOR MAKING SAME

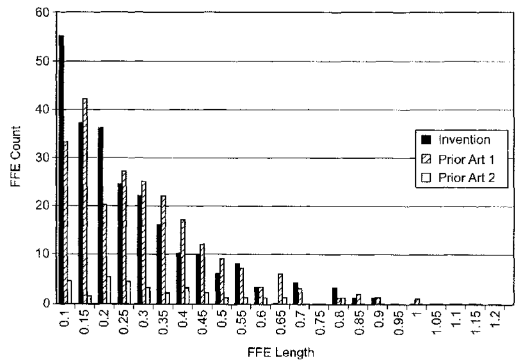

Fig. 1

(57) **Abstract**: Fibrous structure that exhibit a Free Fiber End Count of greater than 100 in the range of free fiber end lengths of from about 0.1 mm to about 0.25 mm as determined by the Free Fiber End Test Method, sanitary tissue products employing same and methods for making same are provided.

WO 2010/022012 A1

FIBROUS STRUCTURES AND METHODS FOR MAKING SAME

FIELD OF THE INVENTION

The present invention relates to fibrous structure that exhibit a Free Fiber End Count of greater than 100 in the range of free fiber end lengths of from about 0.1 mm to about 0.25 mm as determined by the Free Fiber End Test Method, sanitary tissue products comprising same and methods for making same.

BACKGROUND OF THE INVENTION

Fibrous structures, particularly sanitary tissue products comprising fibrous structures, are known to exhibit different values for particular properties. These differences may translate into one fibrous structure being softer or stronger or more absorbent or more flexible or less flexible or exhibit greater stretch or exhibit less stretch, for example, as compared to another fibrous structure.

One property of fibrous structures that is desirable to consumers is softness and/or feel and/or tactile impression of a fibrous structure. It has been found that at least some consumers desire fibrous structures that exhibit a Free Fiber End Count of greater than 100 in the range of free fiber end lengths of from about 0.1 mm to about 0.25 mm as determined by the Free Fiber End Test Method. However, such fibrous structures are not known in the art. Accordingly, there exists a need for fibrous structures that exhibit a Free Fiber End Count of greater than 100 in the range of free fiber end lengths of from about 0.1 mm to about 0.25 mm as determined by the Free Fiber End Test Method, sanitary tissue products comprising such fibrous structures and method for making such fibrous structures.

SUMMARY OF THE INVENTION

The present invention fulfills the need described above by providing fibrous structures that exhibit a Free Fiber End Count of greater than 100 in the range of free fiber end lengths of from about 0.1 mm to about 0.25 mm as determined by the Free Fiber End Test Method.

In one example of the present invention, a fibrous structure that exhibits a Free Fiber End Count of greater than 100 in the range of free fiber end lengths of from about 0.1 mm to about 0.25 mm as determined by the Free Fiber End Test Method is provided.

In another example of the present invention, a fibrous structure that exhibits a Free Fiber End Count of greater than 80 in the range of free fiber end lengths of from about 0.1 mm to about 0.20 mm as determined by the Free Fiber End Test Method is provided.

In still another example of the present invention, a fibrous structure that exhibits a Free Fiber End Count of greater than 40 in the range of free fiber end lengths of from about 0.1 mm to about 0.15 mm as determined by the Free Fiber End Test Method is provided.

In yet another example of the present invention, a single- or multi-ply sanitary tissue product comprising a fibrous structure according to the present invention is provided.

Without being bound by theory, it is believed that fibrous structures having free fiber ends in accordance with the present invention are desired by consumers because the free fiber ends improve softness of fibrous structures and softness is a foundational consumer need/benefit in fibrous structures, especially toilet tissue and facial tissue products. Free fiber ends, in particular, relate to the fuzzy, surface evenness and scratchiness sensory measures. Previous attempts to address the consumers' needs for more softness have focused on increasing the total number of free fiber ends. The free fiber ends count and length distribution of the present invention results in the fibrous structure feeling more like a velvety cloth on its surface.

Accordingly, the present invention provides fibrous structures that exhibit Free Fiber End Counts that result in the fibrous structures being desirable to consumers, sanitary tissue products comprising such fibrous structures and method for making such fibrous structures.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 a graph showing the Free Fiber End Count for an example of a fibrous structure according to the present invention and two prior art fibrous structures;

Fig. 2 is a schematic representation of an example of a fibrous structure in accordance with the present invention;

Fig. 3 is a cross-sectional view of Fig. 2 taken along line 3-3;

Fig. 4 is a schematic representation of a prior art fibrous structure comprising linear elements.

Fig. 5 is an electromicrograph of a portion of a prior art fibrous structure;

Fig. 6 is a schematic representation of an example of a fibrous structure according to the present invention;

Fig. 7 is a cross-section view of Fig. 6 taken along line 7-7;

Fig. 8 is a schematic representation of an example of a fibrous structure according to the present invention;

Fig. 9 is a schematic representation of an example of a fibrous structure according to the present invention;

Fig. 10 is a schematic representation of an example of a fibrous structure according to the present invention;

Fig. 11 is a schematic representation of an example of a fibrous structure comprising various forms of linear elements in accordance with the present invention;

Fig. 12 is a graph showing Overall Softness versus Lint for fibrous structures according to the present invention and prior art fibrous structures;

Fig. 13 is a graph showing Overall Softness versus Total Dry Tensile Strength for fibrous structures according to the present invention and prior art fibrous structures;

Fig. 14 is a schematic representation of an example of a method for making a fibrous structure according to the present invention;

Fig. 15 is a schematic representation a portion of an example of a molding member in according with the present invention;

Fig. 16 is a cross-section view of Fig. 15 taken along line 16-16; and

Fig. 17 is a micrograph shows free fibers ends of a portion of a fibrous structure.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

"Fibrous structure" as used herein means a structure that comprises one or more filaments and/or fibers. In one example, a fibrous structure according to the present invention means an orderly arrangement of filaments and/or fibers within a structure in order to perform a function. Nonlimiting examples of fibrous structures of the present invention include paper, fabrics (including woven, knitted, and non-woven), and absorbent pads (for example for diapers or feminine hygiene products).

Nonlimiting examples of processes for making fibrous structures include known wet-laid papermaking processes and air-laid papermaking processes. Such processes typically include steps of preparing a fiber composition in the form of a suspension in a medium, either wet, more specifically aqueous medium, or dry, more specifically gaseous, i.e. with air as medium. The aqueous medium used for wet-laid processes is oftentimes referred to as a fiber slurry. The fibrous slurry is then used to deposit a plurality of fibers onto a forming wire or belt such that an embryonic fibrous structure is formed, after which drying and/or bonding the fibers together results in a fibrous structure. Further processing the fibrous structure may be carried out such that a finished fibrous structure is formed. For example, in typical papermaking processes, the finished fibrous structure is the fibrous structure that is wound on the reel at the end of papermaking, and may subsequently be converted into a finished product, e.g. a sanitary tissue product.

The fibrous structures of the present invention may be homogeneous or may be layered. If layered, the fibrous structures may comprise at least two and/or at least three and/or at least four and/or at least five layers. In one example, a layered fibrous structure according to the present invention comprises at least one outer layer that comprises hardwood pulp fibers and/or about 100% by weight of the total fibers within the outer layer of hardwood pulp fibers.

In one example, the fibrous structure of the present invention may comprise two or more regions that exhibit different densities. In another example, the fibrous structure of the present invention may exhibit substantially uniform density.

In another example, the fibrous structure of the present invention may exhibit one or more embossments.

The fibrous structures of the present invention may be co-formed fibrous structures.

"Co-formed fibrous structure" as used herein means that the fibrous structure comprises a mixture of at least two different materials wherein at least one of the materials comprises a filament, such as a polypropylene filament, and at least one other material, different from the first material, comprises a solid additive, such as a fiber and/or a particulate. In one example, a co-formed fibrous structure comprises solid additives, such as fibers, such as wood pulp fibers, and filaments, such as polypropylene filaments.

"Solid additive" as used herein means a fiber and/or a particulate.

"Particulate" as used herein means a granular substance or powder.

"Fiber" and/or "Filament" as used herein means an elongate particulate having an apparent length greatly exceeding its apparent width, i.e. a length to diameter ratio of at least about 10. In one example, a "fiber" is an elongate particulate as described above that exhibits a length of less than 5.08 cm (2 in.) and a "filament" is an elongate particulate as described above that exhibits a length of greater than or equal to 5.08 cm (2 in.).

Fibers are typically considered discontinuous in nature. Nonlimiting examples of fibers include wood pulp fibers and synthetic staple fibers such as polyester fibers.

Filaments are typically considered continuous or substantially continuous in nature. Filaments are relatively longer than fibers. Nonlimiting examples of filaments include meltblown and/or spunbond filaments. Nonlimiting examples of materials that can be spun into filaments include natural polymers, such as starch, starch derivatives, cellulose and cellulose derivatives, hemicellulose, hemicellulose derivatives, and synthetic polymers including, but not limited to polyvinyl alcohol filaments and/or polyvinyl alcohol derivative filaments, and thermoplastic polymer filaments, such as polyesters, nylons, polyolefins such as polypropylene filaments, polyethylene filaments, and biodegradable or compostable thermoplastic fibers such as polylactic acid filaments, polyhydroxyalkanoate filaments and polycaprolactone filaments. The filaments may be monocomponent or multicomponent, such as bicomponent filaments.

In one example of the present invention, “fiber” refers to papermaking fibers. Papermaking fibers useful in the present invention include cellulosic fibers commonly known as wood pulp fibers. Applicable wood pulps include chemical pulps, such as Kraft, sulfite, and sulfate pulps, as well as mechanical pulps including, for example, groundwood, thermomechanical pulp and chemically modified thermomechanical pulp. Chemical pulps, however, may be preferred since they impart a superior tactile sense of softness to tissue sheets made therefrom. Pulps derived from both deciduous trees (hereinafter, also referred to as "hardwood") and coniferous trees (hereinafter, also referred to as "softwood") may be utilized. The hardwood and softwood fibers can be blended, or alternatively, can be deposited in layers to provide a stratified web. U.S. Pat. No. 4,300,981 and U.S. Pat. No. 3,994,771 are incorporated herein by reference for the purpose of disclosing layering of hardwood and softwood fibers. Also applicable to the present invention are fibers derived from recycled paper, which may contain any or all of the above categories as well as other non-fibrous materials such as fillers and adhesives used to facilitate the original papermaking.

The hardwood pulps may comprise tropical hardwood pulps, such as eucalyptus pulp fibers and acacia pulp fibers.

The softwood pulps may comprise Northern Softwood Kraft pulps (NSK) and/or Southern Softwood Kraft (SSK) pulps.

In one example of the present invention, the fibrous structure comprises greater than 50% by weight of the total fibers of hardwood pulp fibers.

In addition to the various wood pulp fibers, other cellulosic fibers such as cotton linters, rayon, lyocell and bagasse can be used in this invention. Other sources of cellulose in the form of fibers or capable of being spun into fibers include grasses and grain sources.

"Sanitary tissue product" as used herein means a soft, low density (i.e. < about 0.15 g/cm3) web useful as a wiping implement for post-urinary and post-bowel movement cleaning (toilet tissue), for otorhinolaryngological discharges (facial tissue), and multi-functional absorbent and cleaning uses (absorbent towels). The sanitary tissue product may be convolutedly wound upon itself about a core or without a core to form a sanitary tissue product roll.

In one example, the sanitary tissue product of the present invention comprises a fibrous structure according to the present invention.

The sanitary tissue products and/or fibrous structures of the present invention may exhibit a basis weight of greater than 15 g/m^2 (9.2 lbs/3000 ft^2) to about 120 g/m^2 (73.8 lbs/3000 ft^2) and/or from about 15 g/m^2 (9.2 lbs/3000 ft^2) to about 110 g/m^2 (67.7 lbs/3000 ft^2) and/or from about 20 g/m^2 (12.3 lbs/3000 ft^2) to about 100 g/m^2 (61.5 lbs/3000 ft^2) and/or from about 30 (18.5 lbs/3000 ft^2) to 90 g/m^2 (55.4 lbs/3000 ft^2). In addition, the sanitary tissue products and/or fibrous structures of the present invention may exhibit a basis weight between about 40 g/m^2 (24.6 lbs/3000 ft^2) to about 120 g/m^2 (73.8 lbs/3000 ft^2) and/or from about 50 g/m^2 (30.8 lbs/3000 ft^2) to about 110 g/m^2 (67.7 lbs/3000 ft^2) and/or from about 55 g/m^2 (33.8 lbs/3000 ft^2) to about 105 g/m^2 (64.6 lbs/3000 ft^2) and/or from about 60 g/m^2 (36.9 lbs/3000 ft^2) to 100 g/m^2 (61.5 lbs/3000 ft^2).

The sanitary tissue products of the present invention may exhibit a total dry tensile strength of greater than about 59 g/cm (150 g/in) and/or from about 78 g/cm (200 g/in) to about 394 g/cm (1000 g/in) and/or from about 98 g/cm (250 g/in) to about 335 g/cm (850 g/in). In addition, the sanitary tissue product of the present invention may exhibit a total dry tensile strength of greater than about 196 g/cm (500 g/in) and/or from about 196 g/cm (500 g/in) to about 394 g/cm (1000 g/in) and/or from about 216 g/cm (550 g/in) to about 335 g/cm (850 g/in) and/or from about 236 g/cm (600 g/in) to about 315 g/cm (800 g/in). In one example, the sanitary tissue product exhibits a total dry tensile strength of less than about 394 g/cm (1000 g/in) and/or less than about 335 g/cm (850 g/in).

In another example, the sanitary tissue products of the present invention may exhibit a total dry tensile strength of greater than about 196 g/cm (500 g/in) and/or greater than about 236 g/cm (600 g/in) and/or greater than about 276 g/cm (700 g/in) and/or greater than about 315 g/cm (800 g/in) and/or greater than about 354 g/cm (900 g/in) and/or greater than about 394 g/cm (1000 g/in) and/or from about 315 g/cm (800 g/in) to about 1968 g/cm (5000 g/in) and/or from about 354 g/cm (900 g/in) to about 1181 g/cm (3000 g/in) and/or from about 354 g/cm (900 g/in) to about 984 g/cm (2500 g/in) and/or from about 394 g/cm (1000 g/in) to about 787 g/cm (2000 g/in).

The sanitary tissue products of the present invention may exhibit an initial total wet tensile strength of less than about 78 g/cm (200 g/in) and/or less than about 59 g/cm (150 g/in) and/or less than about 39 g/cm (100 g/in) and/or less than about 29 g/cm (75 g/in).

The sanitary tissue products of the present invention may exhibit an initial total wet tensile strength of greater than about 118 g/cm (300 g/in) and/or greater than about 157 g/cm (400 g/in) and/or greater than about 196 g/cm (500 g/in) and/or greater than about 236 g/cm (600 g/in) and/or greater than about 276 g/cm (700 g/in) and/or greater than about 315 g/cm (800 g/in) and/or greater than about 354 g/cm (900 g/in) and/or greater than about 394 g/cm (1000 g/in) and/or from about 118 g/cm (300 g/in) to about 1968 g/cm (5000 g/in) and/or from about 157 g/cm (400 g/in) to about 1181 g/cm (3000 g/in) and/or from about 196 g/cm (500 g/in) to about 984 g/cm (2500 g/in) and/or from about 196 g/cm (500 g/in) to about 787 g/cm (2000 g/in) and/or from about 196 g/cm (500 g/in) to about 591 g/cm (1500 g/in).

The sanitary tissue products of the present invention may exhibit a density (measured at 95 g/in^2) of less than about 0.60 g/cm^3 and/or less than about 0.30 g/cm^3 and/or less than about 0.20 g/cm^3 and/or less than about 0.10 g/cm^3 and/or less than about 0.07 g/cm^3 and/or less than about 0.05 g/cm^3 and/or from about 0.01 g/cm^3 to about 0.20 g/cm^3 and/or from about 0.02 g/cm^3 to about 0.10 g/cm^3.

The sanitary tissue products of the present invention may exhibit a total absorptive capacity of according to the Horizontal Full Sheet (HFS) Test Method described herein of greater than about 10 g/g and/or greater than about 12 g/g and/or greater than about 15 g/g and/or greater than about 22.5 g/g and/or from about 15 g/g to about 50 g/g and/or to about 40 g/g and/or to about 30 g/g.

The sanitary tissue products of the present invention may exhibit a Vertical Full Sheet (VFS) value as determined by the Vertical Full Sheet (VFS) Test Method described herein of greater than about 5 g/g and/or greater than about 7 g/g and/or greater than about 9 g/g and/or greater than 12.6 g/g and/or from about 9 g/g to about 30 g/g and/or to about 25 g/g and/or to about 20 g/g and/or to about 17 g/g.

The sanitary tissue products of the present invention may be in the form of sanitary tissue product rolls. Such sanitary tissue product rolls may comprise a plurality of connected, but perforated sheets of fibrous structure, that are separably dispensable from adjacent sheets.

The sanitary tissue products of the present invention may comprises additives such as softening agents, wet strength agents (such as temporary wet strength agents and/or permanent wet strength agents), bulk softening agents, lotions, silicones, wetting agents, latexes, especially surface-pattern-applied latexes, dry strength agents such as carboxymethylcellulose and starch, creping adhesives, and other types of additives suitable for inclusion in and/or on sanitary tissue products.

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

"Basis Weight" as used herein is the weight per unit area of a sample reported in lbs/3000 ft^2 or g/m^2 and is measured according to the Basis Weight Test Method described herein.

"Caliper" as used herein means the macroscopic thickness of a fibrous structure. Caliper is measured according to the Caliper Test Method described herein.

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

"Cross Machine Direction" or "CD" as used herein means the direction parallel to the width of the fibrous structure making machine and/or sanitary tissue product manufacturing equipment and perpendicular to the machine direction.

"Ply" as used herein means an individual, integral fibrous structure.

"Plies" as used herein means two or more individual, integral fibrous structures disposed in a substantially contiguous, face-to-face relationship with one another, forming a multi-ply fibrous structure and/or multi-ply sanitary tissue product. It is also contemplated that an individual, integral fibrous structure can effectively form a multi-ply fibrous structure, for example, by being folded on itself.

"Linear element" as used herein means a discrete, unidirectional, uninterrupted portion of a fibrous structure having length of greater than about 4.5 mm. In one example, a linear element may comprise a plurality of non-linear elements. In one example, a linear element in accordance with the present invention is water-resistant. Unless otherwise stated, the linear elements of the present invention are present on a surface of a fibrous structure. The length and/or width and/or height of the linear element and/or linear element forming component within a molding member, which results in a linear element within a fibrous structure, is measured by the Dimensions of Linear Element/Linear Element Forming Component Test Method described herein.

In one example, the linear element and/or linear element forming component is continuous or substantially continuous with a useable fibrous structure, for example in one case one or more 11 cm x 11 cm sheets of fibrous structure.

"Discrete" as it refers to a linear element means that a linear element has at least one immediate adjacent region of the fibrous structure that is different from the linear element.

"Unidirectional" as it refers to a linear element means that along the length of the linear element, the linear element does not exhibit a directional vector that contradicts the linear element's major directional vector.

"Uninterrupted" as it refers to a linear element means that a linear element does not have a region that is different from the linear element cutting across the linear element along its length. Undulations within a linear element such as those resulting from operations such creping and/or foreshortening are not considered to result in regions that are different from the linear element and thus do not interrupt the linear element along its length.

"Water-resistant" as it refers to a linear element means that a linear element retains its structure and/or integrity after being saturated.

"Substantially machine direction (MD) oriented" as it refers to a linear element means that the total length of the linear element that is positioned at an angle of greater than 45° to the cross machine direction is greater than the total length of the linear element that is positioned at an angle of 45° or less to the cross machine direction.

"Substantially cross machine direction (CD) oriented" as it refers to a linear element means that the total length of the linear element that is positioned at an angle of 45° or greater to the machine direction is greater than the total length of the linear element that is positioned at an angle of less than 45° to the machine direction.

Fibrous Structure

The fibrous structures of the present invention may be a single-ply or multi-ply fibrous structure.

In one example of the present invention as shown in Fig. 1, a fibrous structure according to the present invention exhibits a Free Fiber End Count of greater than 100 in the range of free fiber end lengths of from about 0.1 mm to about 0.25 mm as determined by the Free Fiber End Test Method.

In another example of the present invention as shown in Fig. 1, a fibrous structure according to the present invention exhibits a Free Fiber End Count of greater than 80 in the range of free fiber end lengths of from about 0.1 mm to about 0.20 mm as determined by the Free Fiber End Test Method.

In another example of the present invention as shown in Fig. 1, a fibrous structure according to the present invention exhibits a Free Fiber End Count of greater than 40 in the range of free fiber end lengths of from about 0.1 mm to about 0.15 mm as determined by the Free Fiber End Test Method.

In even yet another example of the present invention, a fibrous structure comprises cellulosic pulp fibers. However, other naturally-occurring and/or non-naturally occurring fibers and/or filaments may be present in the fibrous structures of the present invention.

In one example of the present invention, a fibrous structure comprises a throughdried fibrous structure. The fibrous structure may be creped or uncreped. In one example, the fibrous structure is a wet-laid fibrous structure.

The fibrous structure may be incorporated into a single- or multi-ply sanitary tissue product. The sanitary tissue product may be in roll form where it is convolutedly wrapped about itself with or without the employment of a core.

A nonlimiting example of a fibrous structure in accordance with the present invention is shown in Figs. 2 and 3. Figs. 2 and 3 show a fibrous structure 10 comprising one or more linear elements 12. The linear elements 12 are oriented in the machine or substantially the machine direction on the surface 14 of the fibrous structure 10. In one example, one or more of the linear elements 12 may exhibit a length L of greater than about 4.5 mm and/or greater than about 6 mm and/or greater than about 10 mm and/or greater than about 20 mm and/or greater than about 30 mm and/or greater than about 45 mm and/or greater than about 60 mm and/or greater than about 75 mm and/or greater than about 90 mm. For comparison, as shown in Fig. 4, a schematic representation of a commercially available toilet tissue product 20 has a plurality of substantially machine direction oriented linear elements 12 wherein the longest linear element 12 present in the toilet tissue product 20 exhibits a length L^a of 4.3 mm or less. Fig. 5 is a schematic representation of a surface of a commercially available toilet tissue product 30 that comprises substantially machine direction oriented linear elements 12 wherein the longest linear element 12 present in the toilet tissue product 30 exhibits a length L^b of 4.3 mm or less. Even though the linear elements shown in Fig. 5 look continuous, they actually have breaks (not shown) in them along their lengths thus making them have lengths L^b of 4.3 mm or less.

In one example, the width W of one or more of the linear elements 12 is less than about 10 mm and/or less than about 7 mm and/or less than about 5 mm and/or less than about 2 mm and/or less than about 1.7 mm and/or less than about 1.5 mm to about 0 mm and/or to about 0.10 mm and/or to about 0.20 mm. In another example, the linear element height of one or more of the linear elements is greater than about 0.10 mm and/or greater than about 0.50 mm and/or greater than about 0.75 mm and/or greater than about 1 mm to about 4 mm and/or to about 3 mm and/or to about 2.5 mm and/or to about 2 mm.

In another example, the fibrous structure of the present invention exhibits a ratio of linear element height (in mm) to linear element width (in mm) of greater than about 0.35 and/or greater than about 0.45 and/or greater than about 0.5 and/or greater than about 0.75 and/or greater than about 1.

One or more of the linear elements may exhibit a geometric mean of linear element height by linear element of width of greater than about 0.25 mm^2 and/or greater than about 0.35 mm^2 and/or greater than about 0.5 mm^2 and/or greater than about 0.75 mm^2.

As shown in Figs. 2 and 3, the fibrous structure 10 may comprise a plurality of substantially machine direction oriented linear elements 12 that are present on the fibrous structure 10 at a frequency of greater than about 1 linear element/5 cm and/or greater than about 4 linear elements/5 cm and/or greater than about 7 linear elements/5 cm and/or greater than about 15 linear elements/5 cm and/or greater than about 20 linear elements/5 cm and/or greater than about 25 linear elements/5 cm and/or greater than about 30 linear elements/5 cm up to about 50 linear elements/5 cm and/or to about 40 linear elements/5 cm.

In another example of a fibrous structure according to the present invention, the fibrous structure exhibits a ratio of a frequency of linear elements (per cm) to the width (in cm) of one linear element of greater than about 3 and/or greater than about 5 and/or greater than about 7.

The linear elements of the present invention may be in any shape, such as lines, zig-zag lines, serpentine lines. In one example, a linear element does not intersect another linear element.

As shown in Figs. 6 and 7, a fibrous structure 10^a of the present invention may comprise one or more linear elements 12^a. The linear elements 12^a may be oriented on a surface 14^a of a fibrous structure 12^a in any direction such as machine direction, cross machine direction, substantially machine direction oriented, substantially cross machine direction oriented. Two or more linear elements may be oriented in different directions on the same surface of a fibrous structure according to the present invention. In the case of Figs. 6 and 7, the linear elements 12^a are oriented in the cross machine direction. Even though the fibrous structure 10^a comprises only two linear elements 12^a, it is within the scope of the present invention for the fibrous structure 10^a to comprise three or more linear elements 12^a.

The dimensions (length, width and/or height) of the linear elements of the present invention may vary from linear element to linear element within a fibrous structure. As a result, the gap width between neighboring linear elements may vary from one gap to another within a fibrous structure.

In one example, the linear element may comprise an embossment. In another example, the linear element may be an embossed linear element rather than a linear element formed during a fibrous structure making process.

In another example, a plurality of linear elements may be present on a surface of a fibrous structure in a pattern such as in a corduroy pattern.

In still another example, a surface of a fibrous structure may comprise a discontinuous pattern of a plurality of linear elements wherein at least one of the linear elements exhibits a linear element length of greater than about 30 mm.

In yet another example, a surface of a fibrous structure comprises at least one linear element that exhibits a width of less than about 10 mm and/or less than about 7 mm and/or less than about 5 mm and/or less than about 3 mm and/or to about 0.01 mm and/or to about 0.1 mm and/or to about 0.5 mm.

The linear elements may exhibit any suitable height known to those of skill in the art. For example, a linear element may exhibit a height of greater than about 0.10 mm and/or greater than about 0.20 mm and/or greater than about 0.30 mm to about 3.60 mm and/or to about 2.75 mm and/or to about 1.50 mm. A linear element's height is measured irrespective of arrangement of a fibrous structure in a multi-ply fibrous structure, for example, the linear element's height may extend inward within the fibrous structure.

The fibrous structures of the present invention may comprise at least one linear element that exhibits a height to width ratio of greater than about 0.350 and/or greater than about 0.450 and/or greater than about 0.500 and/or greater than about 0.600 and/or to about 3 and/or to about 2 and/or to about 1.

In another example, a linear element on a surface of a fibrous structure may exhibit a geometric mean of height by width of greater than about 0.250 and/or greater than about 0.350 and/or greater than about 0.450 and/or to about 3 and/or to about 2 and/or to about 1.

The fibrous structures of the present invention may comprise linear elements in any suitable frequency. For example, a surface of a fibrous structure may comprises linear elements at a frequency of greater than about 1 linear element/5 cm and/or greater than about 1 linear element/3 cm and/or greater than about 1 linear element/cm and/or greater than about 3 linear elements/cm.

In one example, a fibrous structure comprises a plurality of linear elements that are present on a surface of the fibrous structure at a ratio of frequency of linear elements to width of at least one linear element of greater than about 3 and/or greater than about 5 and/or greater than about 7.

The fibrous structure of the present invention may comprise a surface comprising a plurality of linear elements such that the ratio of geometric mean of height by width of at least one linear element to frequency of linear elements is greater than about 0.050 and/or greater than about 0.750 and/or greater than about 0.900 and/or greater than about 1 and/or greater than about 2 and/or up to about 20 and/or up to about 15 and/or up to about 10.

In addition to one or more linear elements 12^b, as shown in Fig. 8, a fibrous structure 10^b of the present invention may further comprise one or more non-linear elements 16^b. In one example, a non-linear element 16^b present on the surface 14b of a fibrous structure 10^b is water-resistant. In another example, a non-linear element 16^b present on the surface 14^b of a fibrous structure 10^b comprises an embossment. When present on a surface of a fibrous structure, a plurality of non-linear elements may be present in a pattern. The pattern may comprise a geometric shape such as a polygon. Nonlimiting example of suitable polygons are selected from the group consisting of: triangles, diamonds, trapezoids, parallelograms, rhombuses, stars, pentagons, hexagons, octagons and mixtures thereof.

One or more of the fibrous structures of the present invention may form a single- or multi-ply sanitary tissue product. In one example, as shown in Fig. 9, a multi-ply sanitary tissue product 30 comprises a first ply 32 and a second ply 34 wherein the first ply 32 comprises a surface 14^c comprising a plurality of linear elements 12^c, in this case being oriented in the machine direction or substantially machine direction oriented. The plies 32 and 34 are arranged such that the linear elements 12^c extend inward into the interior of the sanitary tissue product 30 rather than outward.

In another example, as shown in Fig. 10, a multi-ply sanitary tissue product 40 comprises a first ply 42 and a second ply 44 wherein the first ply 42 comprises a surface 14^d comprising a plurality of linear elements 12^d, in this case being oriented in the machine direction or substantially machine direction oriented. The plies 42 and 44 are arranged such that the linear elements 12^d extend outward from the surface 14^d of the sanitary tissue product 40 rather than inward into the interior of the sanitary tissue product 40.

As shown in Fig. 11, a fibrous structure 10^c of the present invention may comprise a variety of different forms of linear elements 12^e, alone or in combination, such as serpentines, dashes, MD and/or CD oriented, and the like.

As shown in Fig. 12, it has been surprisingly found that the fibrous structures of the present invention, especially through-air-dried fibrous structures of the present invention, exhibit greater softness at equal lint values compared to prior art fibrous structures, especially prior art through-air-dried fibrous structures.

As shown in Fig. 13, it has been surprisingly found that the fibrous structures of the present invention, especially through-air-dried fibrous structures of the present invention, exhibit greater softness at equal total dry tensile strengths compared to prior art fibrous structures, especially prior art through-air-dried fibrous structures.

Methods for Making Fibrous Structures

The fibrous structures of the present invention may be made by any suitable process known in the art. The method may be a fibrous structure making process that uses a cylindrical dryer such as a Yankee (a Yankee-process) or it may be a Yankeeless process as is used to make substantially uniform density and/or uncreped fibrous structures.

The fibrous structure of the present invention may be made using a molding member. A “molding member" is a structural element that can be used as a support for an embryonic web comprising a plurality of cellulosic fibers and a plurality of synthetic fibers, as well as a forming unit to form, or "mold," a desired microscopical geometry of the fibrous structure of the present invention. The molding member may comprise any element that has fluid-permeable areas and the ability to impart a microscopical three-dimensional pattern to the structure being produced thereon, and includes, without limitation, single-layer and multi-layer structures comprising a stationary plate, a belt, a woven fabric (including Jacquard-type and the like woven patterns), a band, and a roll. In one example, the molding member is a deflection member.

A “reinforcing element” is a desirable (but not necessary) element in some embodiments of the molding member, serving primarily to provide or facilitate integrity, stability, and durability of the molding member comprising, for example, a resinous material. The reinforcing element can be fluid-permeable or partially fluid-permeable, may have a variety of embodiments and weave patterns, and may comprise a variety of materials, such as, for example, a plurality of interwoven yarns (including Jacquard-type and the like woven patterns), a felt, a plastic, other suitable synthetic material, or any combination thereof.

In one example of a method for making a fibrous structure of the present invention, the method comprises the step of contacting an embryonic fibrous web with a deflection member (molding member) such that at least one portion of the embryonic fibrous web is deflected out-of-plane of another portion of the embryonic fibrous web. The phrase “out-of-plane” as used herein means that the fibrous structure comprises a protuberance, such as a dome, or a cavity that extends away from the plane of the fibrous structure. The molding member may comprise a through-air-drying fabric having its filaments arranged to produce linear elements within the fibrous structures of the present invention and/or the through-air-drying fabric or equivalent may comprise a resinous framework that defines deflection conduits that allow portions of the fibrous structure to deflect into the conduits thus forming linear elements within the fibrous structures of the present invention. In addition, a forming wire, such as a foraminous member may be arranged such that linear elements within the fibrous structures of the present invention are formed and/or like the through-air-drying fabric, the foraminous member may comprise a resinous framework that defines deflection conduits that allow portions of the fibrous structure to deflect into the conduits thus forming linear elements within the fibrous structures of the present invention.

In another example of a method for making a fibrous structure of the present invention, the method comprises the steps of:

(a) providing a fibrous furnish comprising fibers; and

(b) depositing the fibrous furnish onto a deflection member such that at least one fiber is deflected out-of-plane of the other fibers present on the deflection member.

In still another example of a method for making a fibrous structure of the present invention, the method comprises the steps of:

(a) providing a fibrous furnish comprising fibers;

(b) depositing the fibrous furnish onto a foraminous member to form an embryonic fibrous web;

(c) associating the embryonic fibrous web with a deflection member such that at least one fiber is deflected out-of-plane of the other fibers present in the embryonic fibrous web; and

(d) drying said embryonic fibrous web such that that the dried fibrous structure is formed.

In another example of a method for making a fibrous structure of the present invention, the method comprises the steps of:

(a) providing a fibrous furnish comprising fibers;

(b) depositing the fibrous furnish onto a first foraminous member such that an embryonic fibrous web is formed;

(c) associating the embryonic web with a second foraminous member which has one surface (the embryonic fibrous web-contacting surface) comprising a macroscopically monoplanar network surface which is continuous and patterned and which defines a first region of deflection conduits and a second region of deflection conduits within the first region of deflection conduits;

(d) deflecting the fibers in the embryonic fibrous web into the deflection conduits and removing water from the embryonic web through the deflection conduits so as to form an intermediate fibrous web under such conditions that the deflection of fibers is initiated no later than the time at which the water removal through the deflection conduits is initiated; and

(e) optionally, drying the intermediate fibrous web; and

(f) optionally, foreshortening the intermediate fibrous web.

The fibrous structures of the present invention may be made by a method wherein a fibrous furnish is applied to a first foraminous member to produce an embryonic fibrous web. The embryonic fibrous web may then come into contact with a second foraminous member that comprises a deflection member to produce an intermediate fibrous web that comprises a network surface and at least one dome region. The intermediate fibrous web may then be further dried to form a fibrous structure of the present invention.

Fig. 14 is a simplified, schematic representation of one example of a continuous fibrous structure making process and machine useful in the practice of the present invention.

As shown in Fig. 14, one example of a process and equipment, represented as 50 for making a fibrous structure according to the present invention comprises supplying an aqueous dispersion of fibers (a fibrous furnish) to a headbox 52 which can be of any convenient design. From headbox 52 the aqueous dispersion of fibers is delivered to a first foraminous member 54 which is typically a Fourdrinier wire, to produce an embryonic fibrous web 56.

The first foraminous member 54 may be supported by a breast roll 58 and a plurality of return rolls 60 of which only two are shown. The first foraminous member 54 can be propelled in the direction indicated by directional arrow 62 by a drive means, not shown. Optional auxiliary units and/or devices commonly associated fibrous structure making machines and with the first foraminous member 54, but not shown, include forming boards, hydrofoils, vacuum boxes, tension rolls, support rolls, wire cleaning showers, and the like.

After the aqueous dispersion of fibers is deposited onto the first foraminous member 54, embryonic fibrous web 56 is formed, typically by the removal of a portion of the aqueous dispersing medium by techniques well known to those skilled in the art. Vacuum boxes, forming boards, hydrofoils, and the like are useful in effecting water removal. The embryonic fibrous web 56 may travel with the first foraminous member 54 about return roll 60 and is brought into contact with a deflection member 64, which may also be referred to as a second foraminous member. While in contact with the deflection member 64, the embryonic fibrous web 56 will be deflected, rearranged, and/or further dewatered.

The deflection member 64 may be in the form of an endless belt. In this simplified representation, deflection member 64 passes around and about deflection member return rolls 66 and impression nip roll 68 and may travel in the direction indicated by directional arrow 70. Associated with deflection member 64, but not shown, may be various support rolls, other return rolls, cleaning means, drive means, and the like well known to those skilled in the art that may be commonly used in fibrous structure making machines.

Regardless of the physical form which the deflection member 64 takes, whether it is an endless belt as just discussed or some other embodiment such as a stationary plate for use in making handsheets or a rotating drum for use with other types of continuous processes, it must have certain physical characteristics. For example, the deflection member may take a variety of configurations such as belts, drums, flat plates, and the like.

First, the deflection member 64 may be foraminous. That is to say, it may possess continuous passages connecting its first surface 72 (or "upper surface" or "working surface"; i.e. the surface with which the embryonic fibrous web is associated, sometimes referred to as the "embryonic fibrous web-contacting surface") with its second surface 74 (or "lower surface"; i.e., the surface with which the deflection member return rolls are associated). In other words, the deflection member 64 may be constructed in such a manner that when water is caused to be removed from the embryonic fibrous web 56, as by the application of differential fluid pressure, such as by a vacuum box 76, and when the water is removed from the embryonic fibrous web 56 in the direction of the deflection member 64, the water can be discharged from the system without having to again contact the embryonic fibrous web 56 in either the liquid or the vapor state.

Second, the first surface 72 of the deflection member 64 may comprise one or more ridges 78 as represented in one example in Figs. 15 and 16. The ridges 78 may be made by any suitable material. For example, a resin may be used to create the ridges 78. The ridges 78 may be continuous, or essentially continuous. In one example, the ridges 78 exhibit a length of greater than about 30 mm. The ridges 78 may be arranged to produce the fibrous structures of the present invention when utilized in a suitable fibrous structure making process. The ridges 78 may be patterned. The ridges 78 may be present on the deflection member 64 at any suitable frequency to produce the fibrous structures of the present invention. The ridges 78 may define within the deflection member 64 a plurality of deflection conduits 80. The deflection conduits 80 may be discrete, isolated, deflection conduits.

The deflection conduits 80 of the deflection member 64 may be of any size and shape or configuration so long at least one produces a linear element in the fibrous structure produced thereby. The deflection conduits 80 may repeat in a random pattern or in a uniform pattern. Portions of the deflection member 64 may comprise deflection conduits 80 that repeat in a random pattern and other portions of the deflection member 64 may comprise deflection conduits 80 that repeat in a uniform pattern.

The ridges 78 of the deflection member 64 may be associated with a belt, wire or other type of substrate. As shown in Figs. 15 and 16, the ridges 78 of the deflection member 64 is associated with a woven belt 82. The woven belt 82 may be made by any suitable material, for example polyester, known to those skilled in the art.

As shown in Fig. 16, a cross sectional view of a portion of the deflection member 64 taken along line 16-16 of Fig. 15, the deflection member 64 can be foraminous since the deflection conduits 80 extend completely through the deflection member 64.

In one example, the deflection member of the present invention may be an endless belt which can be constructed by, among other methods, a method adapted from techniques used to make stencil screens. By "adapted" it is meant that the broad, overall techniques of making stencil screens are used, but improvements, refinements, and modifications as discussed below are used to make member having significantly greater thickness than the usual stencil screen.

Broadly, a foraminous member (such as a woven belt) is thoroughly coated with a liquid photosensitive polymeric resin to a preselected thickness. A mask or negative incorporating the pattern of the preselected ridges is juxtaposed the liquid photosensitive resin; the resin is then exposed to light of an appropriate wave length through the mask. This exposure to light causes curing of the resin in the exposed areas. Unexpected (and uncured) resin is removed from the system leaving behind the cured resin forming the ridges defining within it a plurality of deflection conduits.

In another example, the deflection member can be prepared using as the foraminous member, such as a woven belt, of width and length suitable for use on the chosen fibrous structure making machine. The ridges and the deflection conduits are formed on this woven belt in a series of sections of convenient dimensions in a batchwise manner, i.e. one section at a time. Details of this nonlimiting example of a process for preparing the deflection member follow.

First, a planar forming table is supplied. This forming table is at least as wide as the width of the foraminous woven element and is of any convenient length. It is provided with means for securing a backing film smoothly and tightly to its surface. Suitable means include provision for the application of vacuum through the surface of the forming table, such as a plurality of closely spaced orifices and tensioning means.

A relatively thin, flexible polymeric (such as polypropylene) backing film is placed on the forming table and is secured thereto, as by the application of vacuum or the use of tension. The backing film serves to protect the surface of the forming table and to provide a smooth surface from which the cured photosensitive resins will, later, be readily released. This backing film will form no part of the completed deflection member.

Either the backing film is of a color which absorbs activating light or the backing film is at least semi-transparent and the surface of the forming table absorbs activating light.

A thin film of adhesive, such as 8091 Crown Spray Heavy Duty Adhesive made by Crown Industrial Products Co. of Hebron, Ill., is applied to the exposed surface of the backing film or, alternatively, to the knuckles of the woven belt. A section of the woven belt is then placed in contact with the backing film where it is held in place by the adhesive. The woven belt is under tension at the time it is adhered to the backing film.

Next, the woven belt is coated with liquid photosensitive resin. As used herein, "coated" means that the liquid photosensitive resin is applied to the woven belt where it is carefully worked and manipulated to insure that all the openings (interstices) in the woven belt are filled with resin and that all of the filaments comprising the woven belt are enclosed with the resin as completely as possible. Since the knuckles of the woven belt are in contact with the backing film, it will not be possible to completely encase the whole of each filament with photosensitive resin. Sufficient additional liquid photosensitive resin is applied to the woven belt to form a deflection member having a certain preselected thickness. The deflection member can be from about 0.35 mm (0.014 in.) to about 3.0 mm (0.150 in.) in overall thickness and the ridges can be spaced from about 0.10 mm (0.004 in.) to about 2.54 mm (0.100 in.) from the mean upper surface of the knuckles of the woven belt. Any technique well known to those skilled in the art can be used to control the thickness of the liquid photosensitive resin coating. For example, shims of the appropriate thickness can be provided on either side of the section of deflection member under construction; an excess quantity of liquid photosensitive resin can be applied to the woven belt between the shims; a straight edge resting on the shims and can then be drawn across the surface of the liquid photosensitive resin thereby removing excess material and forming a coating of a uniform thickness.

Suitable photosensitive resins can be readily selected from the many available commercially. They are typically materials, usually polymers, which cure or cross-link under the influence of activating radiation, usually ultraviolet (UV) light. References containing more information about liquid photosensitive resins include Green et al, "Photocross-linkable Resin Systems," J. Macro. Sci-Revs. Macro. Chem, C21(2), 187-273 (1981-82); Boyer, "A Review of Ultraviolet Curing Technology," Tappi Paper Synthetics Conf. Proc., Sept. 25-27, 1978, pp 167-172; and Schmidle, "Ultraviolet Curable Flexible Coatings," J. of Coated Fabrics, 8, 10-20 (July, 1978). All the preceding three references are incorporated herein by reference. In one example, the ridges are made from the Merigraph series of resins made by Hercules Incorporated of Wilmington, Del.

Once the proper quantity (and thickness) of liquid photosensitive resin is coated on the woven belt, a cover film is optionally applied to the exposed surface of the resin. The cover film, which must be transparent to light of activating wave length, serves primarily to protect the mask from direct contact with the resin.

A mask (or negative) is placed directly on the optional cover film or on the surface of the resin. This mask is formed of any suitable material which can be used to shield or shade certain portions of the liquid photosensitive resin from light while allowing the light to reach other portions of the resin. The design or geometry preselected for the ridges is, of course, reproduced in this mask in regions which allow the transmission of light while the geometries preselected for the gross foramina are in regions which are opaque to light.

A rigid member such as a glass cover plate is placed atop the mask and serves to aid in maintaining the upper surface of the photosensitive liquid resin in a planar configuration.

The liquid photosensitive resin is then exposed to light of the appropriate wave length through the cover glass, the mask, and the cover film in such a manner as to initiate the curing of the liquid photosensitive resin in the exposed areas. It is important to note that when the described procedure is followed, resin which would normally be in a shadow cast by a filament, which is usually opaque to activating light, is cured. Curing this particular small mass of resin aids in making the bottom side of the deflection member planar and in isolating one deflection conduit from another.

After exposure, the cover plate, the mask, and the cover film are removed from the system. The resin is sufficiently cured in the exposed areas to allow the woven belt along with the resin to be stripped from the backing film.

Uncured resin is removed from the woven belt by any convenient means such as vacuum removal and aqueous washing.

A section of the deflection member is now essentially in final form. Depending upon the nature of the photosensitive resin and the nature and amount of the radiation previously supplied to it, the remaining, at least partially cured, photosensitive resin can be subjected to further radiation in a post curing operation as required.

The backing film is stripped from the forming table and the process is repeated with another section of the woven belt. Conveniently, the woven belt is divided off into sections of essentially equal and convenient lengths which are numbered serially along its length. Odd numbered sections are sequentially processed to form sections of the deflection member and then even numbered sections are sequentially processed until the entire belt possesses the characteristics required of the deflection member. The woven belt may be maintained under tension at all times.

In the method of construction just described, the knuckles of the woven belt actually form a portion of the bottom surface of the deflection member. The woven belt can be physically spaced from the bottom surface.

Multiple replications of the above described technique can be used to construct deflection members having the more complex geometries.

The deflection member of the present invention may be made or partially made according to U.S. Patent No. 4,637,859, issued Jan. 20, 1987 to Trokhan.

As shown in Fig. 14, after the embryonic fibrous web 56 has been associated with the deflection member 64, fibers within the embryonic fibrous web 56 are deflected into the deflection conduits present in the deflection member 64. In one example of this process step, there is essentially no water removal from the embryonic fibrous web 56 through the deflection conduits after the embryonic fibrous web 56 has been associated with the deflection member 64 but prior to the deflecting of the fibers into the deflection conduits. Further water removal from the embryonic fibrous web 56 can occur during and/or after the time the fibers are being deflected into the deflection conduits. Water removal from the embryonic fibrous web 56 may continue until the consistency of the embryonic fibrous web 56 associated with deflection member 64 is increased to from about 25% to about 35%. Once this consistency of the embryonic fibrous web 56 is achieved, then the embryonic fibrous web 56 is referred to as an intermediate fibrous web 84. During the process of forming the embryonic fibrous web 56, sufficient water may be removed, such as by a noncompressive process, from the embryonic fibrous web 56 before it becomes associated with the deflection member 64 so that the consistency of the embryonic fibrous web 56 may be from about 10% to about 30%.

While applicants decline to be bound by any particular theory of operation, it appears that the deflection of the fibers in the embryonic web and water removal from the embryonic web begin essentially simultaneously. Embodiments can, however, be envisioned wherein deflection and water removal are sequential operations. Under the influence of the applied differential fluid pressure, for example, the fibers may be deflected into the deflection conduit with an attendant rearrangement of the fibers. Water removal may occur with a continued rearrangement of fibers. Deflection of the fibers, and of the embryonic fibrous web, may cause an apparent increase in surface area of the embryonic fibrous web. Further, the rearrangement of fibers may appear to cause a rearrangement in the spaces or capillaries existing between and/or among fibers.

It is believed that the rearrangement of the fibers can take one of two modes dependent on a number of factors such as, for example, fiber length. The free ends of longer fibers can be merely bent in the space defined by the deflection conduit while the opposite ends are restrained in the region of the ridges. Shorter fibers, on the other hand, can actually be transported from the region of the ridges into the deflection conduit (The fibers in the deflection conduits will also be rearranged relative to one another). Naturally, it is possible for both modes of rearrangement to occur simultaneously.

As noted, water removal occurs both during and after deflection; this water removal may result in a decrease in fiber mobility in the embryonic fibrous web. This decrease in fiber mobility may tend to fix and/or freeze the fibers in place after they have been deflected and rearranged. Of course, the drying of the web in a later step in the process of this invention serves to more firmly fix and/or freeze the fibers in position.

Any convenient means conventionally known in the papermaking art can be used to dry the intermediate fibrous web 84. Examples of such suitable drying process include subjecting the intermediate fibrous web 84 to conventional and/or flow-through dryers and/or Yankee dryers.

In one example of a drying process, the intermediate fibrous web 84 in association with the deflection member 64 passes around the deflection member return roll 66 and travels in the direction indicated by directional arrow 70. The intermediate fibrous web 84 may first pass through an optional predryer 86. This predryer 86 can be a conventional flow-through dryer (hot air dryer) well known to those skilled in the art. Optionally, the predryer 86 can be a so-called capillary dewatering apparatus. In such an apparatus, the intermediate fibrous web 84 passes over a sector of a cylinder having preferential-capillary-size pores through its cylindrical-shaped porous cover. Optionally, the predryer 86 can be a combination capillary dewatering apparatus and flow-through dryer. The quantity of water removed in the predryer 86 may be controlled so that a predried fibrous web 88 exiting the predryer 86 has a consistency of from about 30% to about 98%. The predried fibrous web 88, which may still be associated with deflection member 64, may pass around another deflection member return roll 66 and as it travels to an impression nip roll 68. As the predried fibrous web 88 passes through the nip formed between impression nip roll 68 and a surface of a Yankee dryer 90, the ridge pattern formed by the top surface 72 of deflection member 64 is impressed into the predried fibrous web 88 to form a linear element imprinted fibrous web 92. The imprinted fibrous web 92 can then be adhered to the surface of the Yankee dryer 90, for example via a creping adhesive, where it can be dried to a consistency of at least about 95%.

The imprinted fibrous web 92 can then be foreshortened by creping the imprinted fibrous web 92 with a creping blade 94, for example engaged at a creping angle of from about 76° to about 85°, to remove the imprinted fibrous web 92 from the surface of the Yankee dryer 90 resulting in the production of a creped fibrous structure 96 in accordance with the present invention. As used herein, foreshortening refers to the reduction in length of a dry (having a consistency of at least about 90% and/or at least about 95%) fibrous web which occurs when energy is applied to the dry fibrous web in such a way that the length of the fibrous web is reduced and the fibers in the fibrous web are rearranged with an accompanying disruption of fiber-fiber bonds. Foreshortening can be accomplished in any of several well-known ways. One common method of foreshortening is creping. The creped fibrous structure 96 may be subjected to post processing steps such as calendaring, tuft generating operations, and/or embossing and/or converting.

In one example, the fibrous structure comprises a continuous or substantially continuous pattern of substantially machine direction-oriented tufted fibers.

In addition to the Yankee fibrous structure making process/method, the fibrous structures of the present invention may be made using a Yankeeless fibrous structure making process/method. Such a process oftentimes utilizes transfer fabrics to permit rush transfer of the embryonic fibrous web prior to drying. The fibrous structures produced by such a Yankeeless fibrous structure making process oftentimes a substantially uniform density.

The molding member/deflection member of the present invention may be utilized to imprint linear elements into a fibrous structure during a through-air-drying operation.

However, such molding members/deflection members may also be utilized as forming members upon which a fiber slurry is deposited.

In one example, the linear elements of the present invention may be formed by a plurality of non-linear elements, such as embossments and/or protrusions and/or depressions formed by a molding member, that are arranged in a line having an overall length of greater than about 4.5 mm and/or greater than about 6 mm and/or greater than about 10 mm and/or greater than about 20 mm and/or greater than about 30 mm and/or greater than about 45 mm and/or greater than about 60 mm and/or greater than about 75 mm and/or greater than about 90 mm.

In addition to imprinting linear elements into fibrous structures during a fibrous structure making process/method, linear elements may be created in a fibrous structure during a converting operation of a fibrous structure. For example, linear elements may be imparted to a fibrous structure by embossing linear elements into a fibrous structure.

Nonlimiting Example

A fibrous structure in accordance with the present invention is prepared using a fibrous structure making machine having a layered headbox having a top chamber, a center chamber, and a bottom chamber.

A hardwood stock chest is prepared with eucalyptus fiber having a consistency of about 3.0% by weight. A blended stock chest is prepared with eucalyptus fiber, NSK fiber, bleached broke fiber and machine broke fiber with a final consistency of about 2.5% by weight. A wet-strength additive, Cytec's Parez 750C, is added to the thick stock of the blended stock chest at about 2.4 lbs. per ton of dry fiber.

The eucalyptus fiber slurry is pumped through the top headbox chamber Yankee-side), a blend of eucalyptus fiber, NSK fiber, bleached broke fiber and machine broke fiber slurry is pumped through the center headbox chamber and a blend of eucalyptus fiber, NSK fiber, bleached broke fiber and machine broke fiber slurry is pumped through the bottom headbox chamber and delivered in superposed relation into the nip of the twin wire-forming nip to form thereon a three-layer embryonic web, of which about 32% of the top side is made up of pure eucalyptus fibers, center is made up of about 40% of a blend of eucalyptus fiber, NSK fiber, bleached broke fiber and machine broke fiber and the bottom side is made up of about 28% of a blend of eucalyptus fiber, NSK fiber, bleached broke fiber and machine broke fiber. Dewatering occurs through the outer wire and the inner wire and is assisted by wire vacuum boxes. The outer wire is an ASTEN-JOHNSON INTEGRA SFT and the inner wire is ASTEN-JOHNSON MONOFLEX 661. The speed of the outer wire and inner wire is about 3429 fpm (feet per minute).

The embryonic wet web is transferred from the carrier (inner) wire, at a fiber consistency of about 15% at the point of transfer, to a patterned drying fabric. The speed of the patterned drying fabric is about 3500 fpm (feet per minute). The drying fabric is designed to yield a pattern of substantially machine direction oriented linear channels having a continuous network of high density (knuckle) areas. This drying fabric is formed by casting an impervious resin surface onto a fiber mesh supporting fabric. The supporting fabric is a 127 x 52 filament, dual layer mesh. The thickness of the resin cast is about 11 mils above the supporting fabric.

Further de-watering is accomplished by vacuum assisted drainage until the web has a fiber consistency of about 20% to 30%.

While remaining in contact with the patterned drying fabric, the web is pre-dried by air blow-through pre-dryers to a fiber consistency of about 60% by weight.

After the pre-dryers, the semi-dry web is transferred to the Yankee dryer and adhered to the surface of the Yankee dryer with a sprayed a creping adhesive coating. The coating is a blend consisting of Georgia Pacific's Unicrepe 457T20 and Vinylon Works' Vinylon 8844 at a ratio of about 92 to 8, respectively. The fiber consistency is increased to about 97% before the web is dry creped from the Yankee with a doctor blade.

The doctor blade has a bevel angle of about 25 degrees and is positioned with respect to the Yankee dryer to provide an impact angle of about 81 degrees. The Yankee dryer is operated at a temperature of about 350°F (177°C) and a speed of about 3500 fpm. The fibrous structure is wound in a roll using a surface driven reel drum having a surface speed of about 2993 feet per minute. The fibrous structure may be subjected to post treatments such as embossing and/or tuft generating or application of a chemical surface softening. The fibrous structure may be subsequently converted into a two-ply sanitary tissue product having a basis weight of about 47.25 g/m^2. For each ply, the outer layer having the eucalyptus fiber furnish is oriented toward the outside in order to form the consumer facing surfaces of the two-ply sanitary tissue product.

The sanitary tissue product is soft, flexible and absorbent.

Test Methods

Unless otherwise specified, all tests described herein including those described under the Definitions section and the following test methods are conducted on samples that have been conditioned in a conditioned room at a temperature of 73°F ± 4°F (about 23°C ± 2.2°C) and a relative humidity of 50% ± 10% for 2 hours prior to the test. All plastic and paper board packaging materials must be carefully removed from the paper samples prior to testing. Discard any damaged product. All tests are conducted in such conditioned room.

Basis Weight Test Method

Basis weight of a fibrous structure sample is measured by selecting twelve (12) usable units (also referred to as sheets) of the fibrous structure and making two stacks of six (6) usable units each. Perforations, if any, must be aligned on the same side when stacking the usable units. A precision cutter is used to cut each stack into exactly 8.89 cm x 8.89 cm (3.5 in. x 3.5 in.) squares. The two stacks of cut squares are combined to make a basis weight pad of twelve (12) squares thick. The basis weight pad is then weighed on a top loading balance with a minimum resolution of 0.01 g. The top loading balance must be protected from air drafts and other disturbances using a draft shield. Weights are recorded when the readings on the top loading balance become constant. The Basis Weight is calculated as follows:

$$\text{Basis Weight (lbs/3000 ft}^2\text{)} = \frac{\text{Weight of basis weight pad (g) x 3000 ft}^2}{\text{453.6 g/lbs x 12 (usable units) x [12.25 in}^2\text{ (Area of basis weight pad)/144 in}^2\text{]}}$$

$$\text{Basis Weight (g/m}^2\text{)} = \frac{\text{Weight of basis weight pad (g) x 10,000 cm}^2\text{/m}^2}{\text{79.0321 cm}^2\text{ (Area of basis weight pad) x 12 (usable units)}}$$

Total Dry Tensile Strength Test Method

Remove five (5) strips of four (4) usable units (also referred to as sheets) of fibrous structures and stack one on top of the other to form a long stack with the perforations between the sheets coincident. Identify sheets 1 and 3 for machine direction tensile measurements and sheets 2 and 4 for cross direction tensile measurements. Next, cut through the perforation line using a paper cutter (JDC-1-10 or JDC-1-12 with safety shield from Thwing-Albert Instrument Co. of Philadelphia, Pa.) to make 4 separate stacks. Make sure stacks 1 and 3 are still identified for machine direction testing and stacks 2 and 4 are identified for cross direction testing.

Cut two 1 inch (2.54 cm) wide strips in the machine direction from stacks 1 and 3. Cut two 1 inch (2.54 cm) wide strips in the cross direction from stacks 2 and 4. There are now four 1 inch (2.54 cm) wide strips for machine direction tensile testing and four 1 inch (2.54 cm) wide strips for cross direction tensile testing. For these finished product samples, all eight 1 inch (2.54 cm) wide strips are five usable units (sheets) thick.

For the actual measurement of the total dry tensile strength use a Thwing-Albert Intelect II Standard Tensile Tester (Thwing-Albert Instrument Co. of Philadelphia, Pa.). Insert the flat face clamps into the unit and calibrate the tester according to the instructions given in the operation manual of the Thwing-Albert Intelect II. Set the instrument crosshead speed to 4.00 in/min (10.16 cm/min) and the 1st and 2nd gauge lengths to 2.00 inches (5.08 cm). The break sensitivity is set to 20.0 grams and the sample width is set to 1.00 inch (2.54 cm) and the sample thickness is set to 0.3937 inch (1 cm). The energy units are set to TEA and the tangent modulus (Modulus) trap setting is set to 38.1 g.

Take one of the fibrous structure sample strips and place one end of it in one clamp of the tensile tester. Place the other end of the fibrous structure sample strip in the other clamp. Make sure the long dimension of the fibrous structure sample strip is running parallel to the sides of the tensile tester. Also make sure the fibrous structure sample strips are not overhanging to the either side of the two clamps. In addition, the pressure of each of the clamps must be in full contact with the fibrous structure sample strip.

After inserting the fibrous structure sample strip into the two clamps, the instrument tension can be monitored. If it shows a value of 5 grams or more, the fibrous structure sample strip is too taut. Conversely, if a period of 2-3 seconds passes after starting the test before any value is recorded, the fibrous structure sample strip is too slack.

Start the tensile tester as described in the tensile tester instrument manual. The test is complete after the crosshead automatically returns to its initial starting position. When the test is complete, read and record the following with units of measure:

Peak Load Tensile (Tensile Strength) (g/in)

Test each of the samples in the same manner, recording the above measured value from each test.

<u>Calculations:</u>

Total Dry Tensile (TDT) = Peak Load MD Tensile (g/in) + Peak Load CD Tensile (g/in)

<u>Free Fiber End Test Method</u>

The Free Fiber End Count is measured using the Free Fiber End Test Method described below.

A fibrous structure sample to be tested is prepared as follows. If the fibrous structure is a multi-ply fibrous structure, separate the outermost plies being careful to not damage the plies. The outer surfaces of the outermost plies in a multi-ply fibrous structure will be the surfaces tested in this test.

If the fibrous structure is a single-ply fibrous structure, then both sides of the single-ply fibrous structure will be tested in this test.

All fibrous structure samples to be tested under this test should only be handled by the fibrous structure samples' edges.

A Kayeness or equivalent Coefficient of Friction (COF) Tester, from Dynisco L.L.C. of Franklin, MA is used in the test. A piece of 100% cotton fabric (square weave fabric; 58 warps/inch and 68 shutes/inch; warp filaments having a diameter of 0.012 in. and the shute filaments having a diameter of 0.010 in.) having a Coefficient of Friction of approximately 0.203 is cut and placed on a surface of the moveable base of the Coefficient of Friction Tester. The cotton fabric is taped to the surface of the moveable based so that it does not interfere with movement on the side support rails.

Cut a ¾ inch wide X 1 ½ inch long strip from a fibrous structure to be tested. The strip should be cut from the fibrous structure at an angle of 45° to the MD and CD of the fibrous structure.

Tape the fibrous structure strip to a sled of the Coefficient of Friction Tester with Scotch tape such that the surface of the fibrous structure to be tested is facing outward from the sled. Place the sled on the moveable base and start the COF Tester. Allow the tester to run until the sled has traveled 2 ½ inches along the cotton fabric. The pressure applied to the fibrous structure strip is 5 g/cm^2. This "brushing" sufficiently orients the free-fiber-ends in an upstanding disposition to facilitate counting them but care must be exerted to avoid breaking substantial numbers of interfiber bonds during the brushing inasmuch as that would precipitate spurious free-fiber-ends.

Remove the fibrous structure strip from the sled. Reattach the fibrous structure strip to the sled with ¾ inch Scotch tape such that the drag will be in the opposite direction from the original motion and repeat the run for the same distance as before.

Remove the fibrous structure strip and prepare it for examination. The surface of the fibrous structure strip that has been in contact with the cotton fabric is the side to be examined.

Fold the fibrous structure strip in half across an edge of a glass slide cover slip (18 mm square, Number 1 ½ VWR International, West Chester, PA, #48376-02 or equivalent) such that fold line runs across the narrower dimension of the fibrous structure strip and place glass slide cover slip and fibrous structure strip on a clean glass slide (1 inch x 3 inch (2 per sample) VWR International, West Chester, PA, #48300-047 or equivalent).

On another clean glass slide mark two lines ½ inch apart in the middle of the glass slide with a diamond etching pen. Fill in the etched line with a felt tip marker for greater clarity in reading the edges of the measurement area. Place this glass slide over the glass slide cover slip and fibrous structure strip such that the glass slide cover slip and fibrous structure strip is sandwiched between the two glass slides and the etched lines are against the folded fibrous structure strip and extend vertically form the folded edge of the fibrous structure strip. Secure the sandwich arrangement together with ¾ inch Scotch tape.

Using the Image Analysis Measure Tool (a Light/Stereo microscope, with digital camera – 140X magnification, for example a Nikon DXM1200F and an image analysis program (Image Pro available from Media Cybernetics, Inc, Bethesda, MD), place a calibrated stage micrometer onto the microscope stage and trace various scaled lengths of the micrometer between 0.1 mm and 1.0 mm for calibration. Verify calibration and record. Place the fibrous structure strip arrangement under the lens of the microscope, using the same magnification as for the micrometer, so that the edge that is folded over the glass cover slide slip is projected onto the screen/monitor. Lenses and distances should be adjusted so the total magnification is either 140X. Project the image so that the magnification is 140X. All fibers that have a visible loose end extending at least 0.1 mm from the surface of the folded fibrous structure strip should be measured and counted. Individual fibers are traced to determine fiber length using the Image Pro software and are measured, counted and recorded. Starting at one etched line and going to the other etched line, the length of each free fiber end is measured. The focus is adjusted so each fiber to be counted is clearly identified. A free fiber end is defined as any fiber with one end attached to the fibrous structure matrix, and the other end projecting out of, and not returning back into, the fibrous structure matrix. Examples of free fiber ends in a fibrous structure are shown in Fig. 17. In other words, only fibers that have a visible loose (unbonded) or free end and having a free-end length of about 0.1 mm or greater are counted. Fibers that have no visible free end are not counted. Fibers having both ends free are also not counted. The length of each free fiber end is measured by tracing from the point at which it leaves the tissue matrix to its end. The length is measured using a mouse, light pen, or other suitable tracing device. The measurements are reported in millimeters and are stored in the image analysis text file. Data is transferred to a Microsoft Excel spreadsheet for sorting of the fiber lengths. The total number of free fiber ends (excluding free fiber ends less than 0.1 mm long) is calculated.

The total number of free fiber ends within a certain length range ("Free Fiber End Count") can be calculated.

The dimensions and values disclosed herein are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each such dimension is intended to mean both the recited value and a functionally equivalent range surrounding that value. For example, a dimension disclosed as "40 mm" is intended to mean "about 40 mm."

Every document cited herein, including any cross referenced or related patent or application, is hereby incorporated herein by reference in its entirety unless expressly excluded or otherwise limited. The citation of any document is not an admission that it is prior art with respect to any invention disclosed or claimed herein or that it alone, or in any combination with any other reference or references, teaches, suggests or discloses any such invention. Further, to the extent that any meaning or definition of a term in this document conflicts with any meaning or definition of the same term in a document incorporated by reference, the meaning or definition assigned to that term in this document shall govern.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

What is claimed is:

1. A fibrous structure comprising a plurality of fibers wherein the fibrous structure exhibits a Free Fiber End Count of greater than 100 in the range of free fiber end lengths of from 0.1 mm to 0.25 mm as determined by the Free Fiber End Test Method.

2. The fibrous structure according to Claim 1 wherein the fibers are selected from the group consisting of hardwood pulp fibers, softwood pulp fibers and mixtures thereof, preferably wherein the hardwood pulp fibers comprise tropical hardwood pulp fibers, more preferably wherein the tropical hardwood pulp fibers comprise eucalyptus pulp fibers, preferably wherein greater than 50% by weight of the fibers comprise hardwood pulp fibers.

3. The fibrous structure according to any of the preceding claims wherein the fibrous structure further comprises a wet strength agent, preferably wherein the wet strength agent comprises a temporary wet strength agent.

4. The fibrous structure according to any of the preceding claims wherein the fibrous structure exhibits a total dry tensile strength of greater than 59 g/cm (150 g/in).

5. The fibrous structure according to any of the preceding claims wherein the fibrous structure exhibits a basis weight of greater than 15 gsm to 120 gsm as measured according to the Basis Weight Test Method.

6. The fibrous structure according to any of the preceding claims wherein the fibrous structure is a layered fibrous structure, preferably wherein the layered fibrous structure comprises at least one outer layer that comprises 100% by weight of the total fibers within the outer layer of hardwood pulp fibers.

7. The fibrous structure according to any of the preceding claims wherein the fibrous structure is a homogeneous fibrous structure.

8. The fibrous structure according to any of the preceding claims wherein the fibrous structure is uncreped.

9. The fibrous structure according to any of the preceding claims wherein the fibrous structure is creped.

10. The fibrous structure according to any of the preceding claims wherein the fibrous structure exhibits substantially uniform density.

11. The fibrous structure according to any of the preceding claims wherein the fibrous structure comprise two or more regions that exhibit different densities.

12. The fibrous structure according to any of the preceding claims wherein the fibrous structure is a through-air-dried fibrous structure, preferably wherein a surface of the through-air-dried fibrous structure comprises a pattern, more preferably wherein the pattern comprises substantially MD oriented lines.

13. The fibrous structure according to any of the preceding claims wherein the fibrous structure comprises one or more embossments.

14. The fibrous structure according to any of the preceding claims wherein the fibrous structure exhibits a softness that is greater than the softness of a fibrous structure that exhibits a Free Fiber End Count of less than 100 in the range of free fiber end lengths of from 0.1 mm to 0.25 mm as determined by the Free Fiber End Test Method at the same lint value.

15. The fibrous structure according to any of the preceding claims wherein the fibrous structure exhibits a softness that is greater than the softness of a fibrous structure that exhibits a Free Fiber End Count of less than 100 in the range of free fiber end lengths of from 0.1 mm to 0.25 mm as determined by the Free Fiber End Test Method at the same total dry tensile strength.

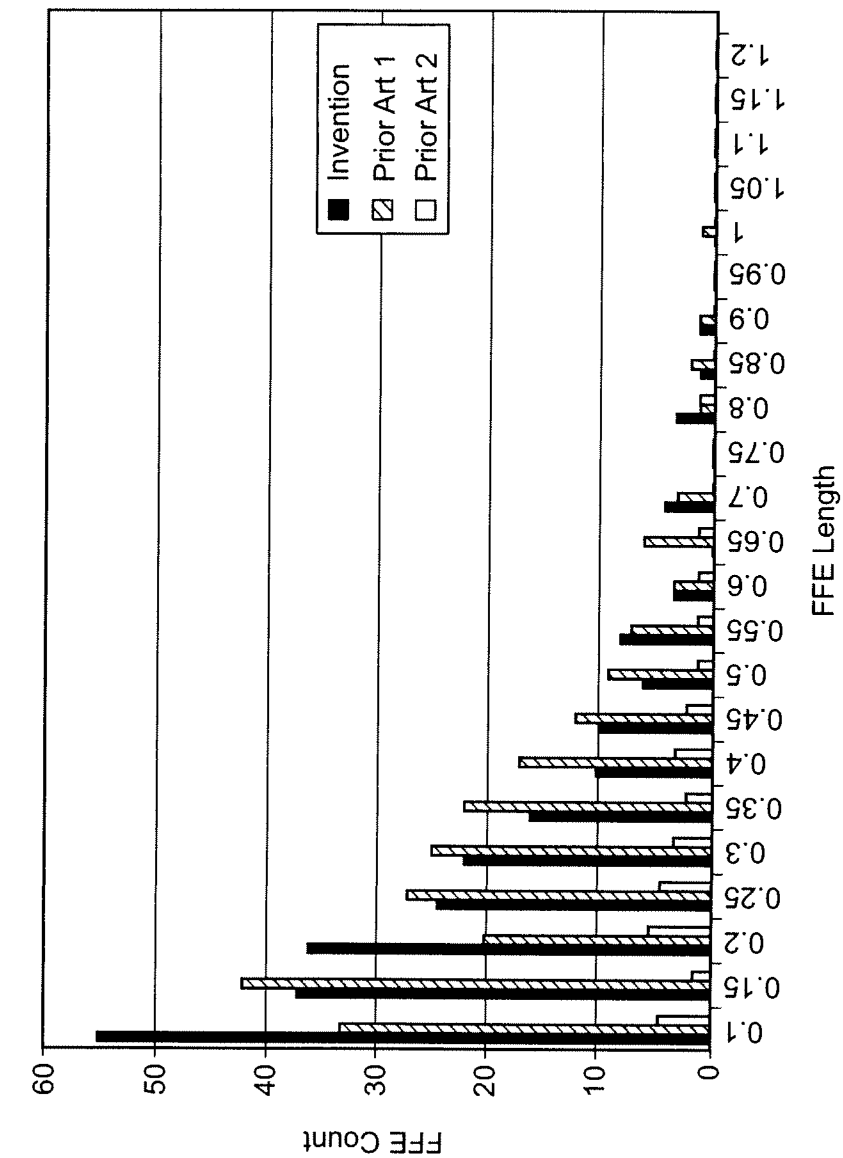
Invention
Prior Art 1
Prior Art 2
FFE Count
FFE Length
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Fig. 1

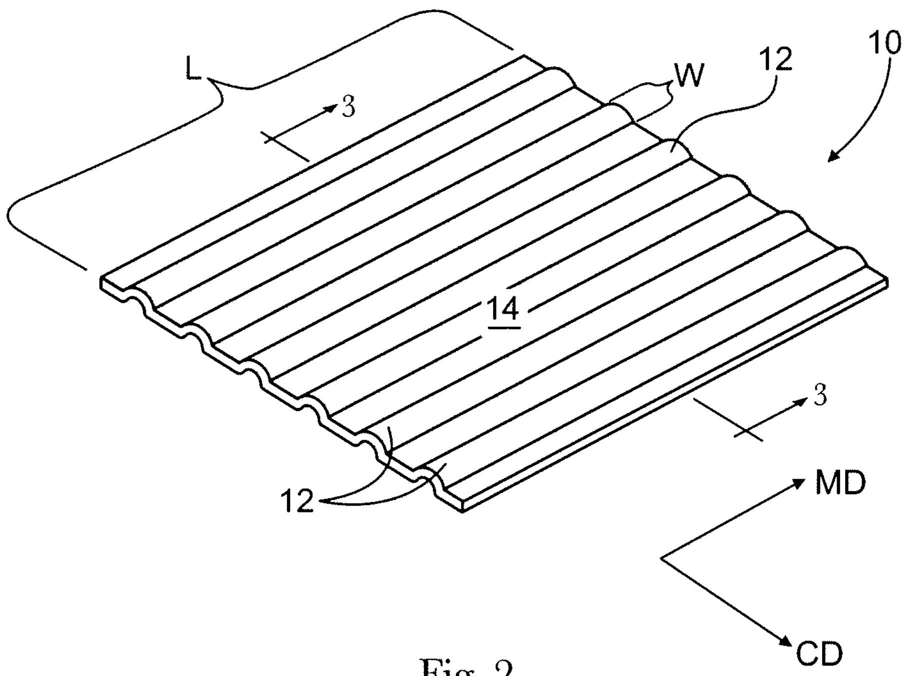

Fig. 2

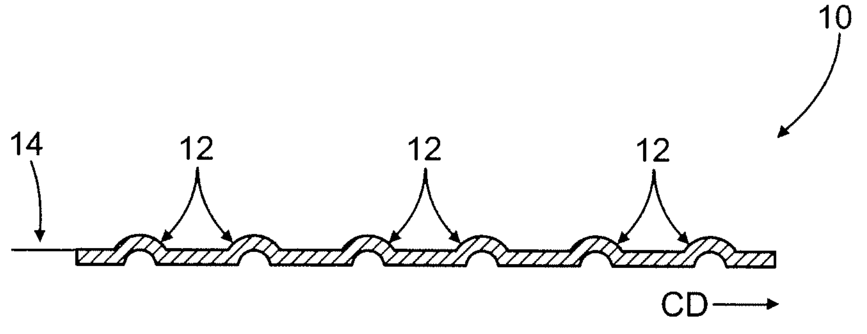

Fig. 3

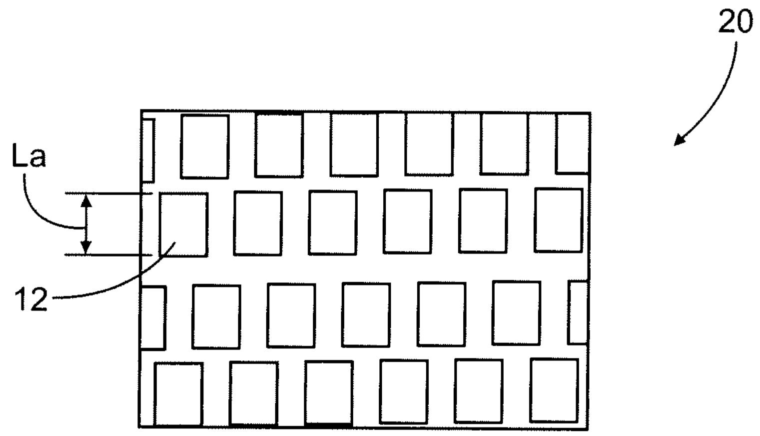

Fig. 4

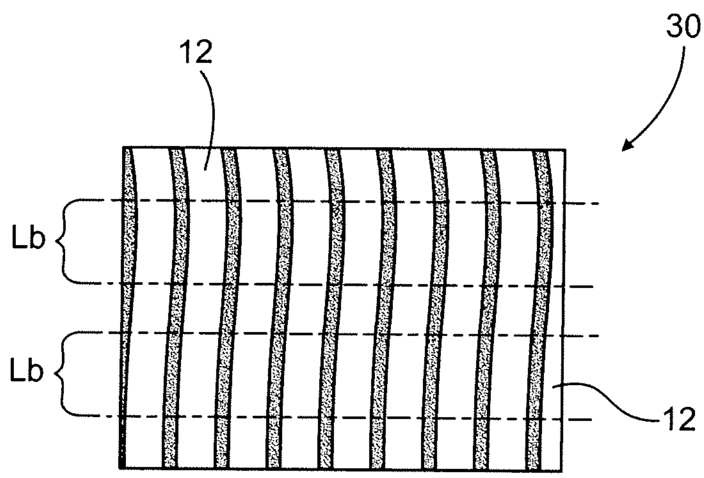

Fig. 5

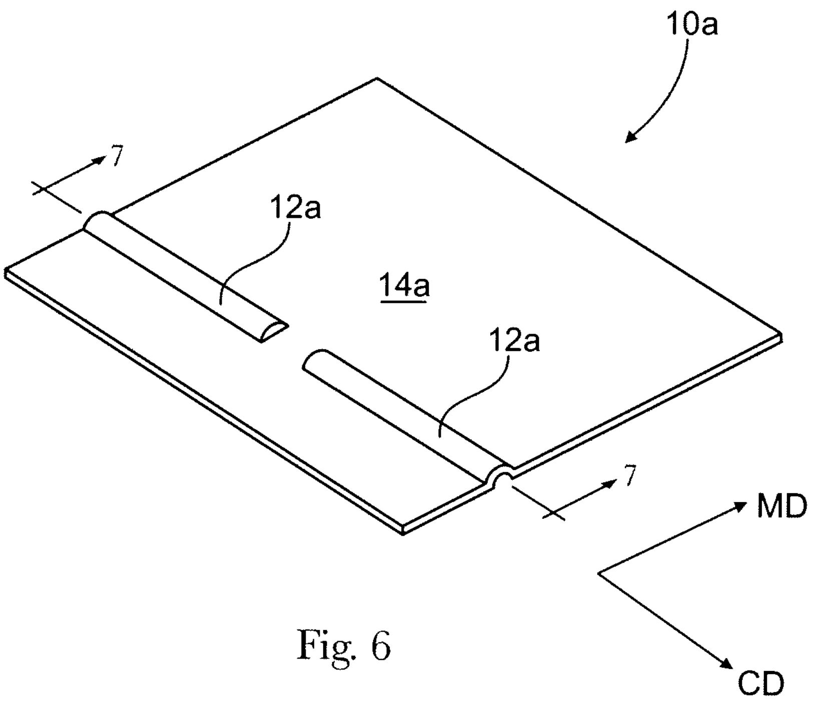

Fig. 6

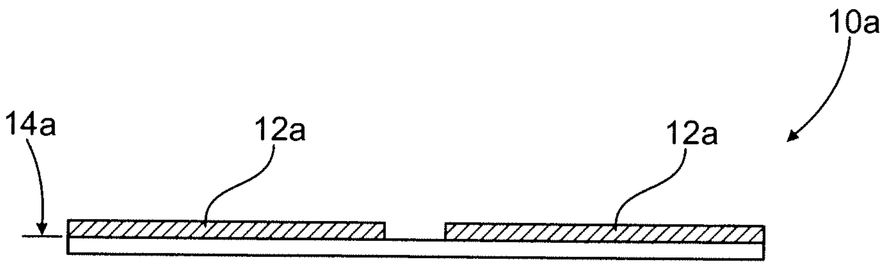

Fig. 7

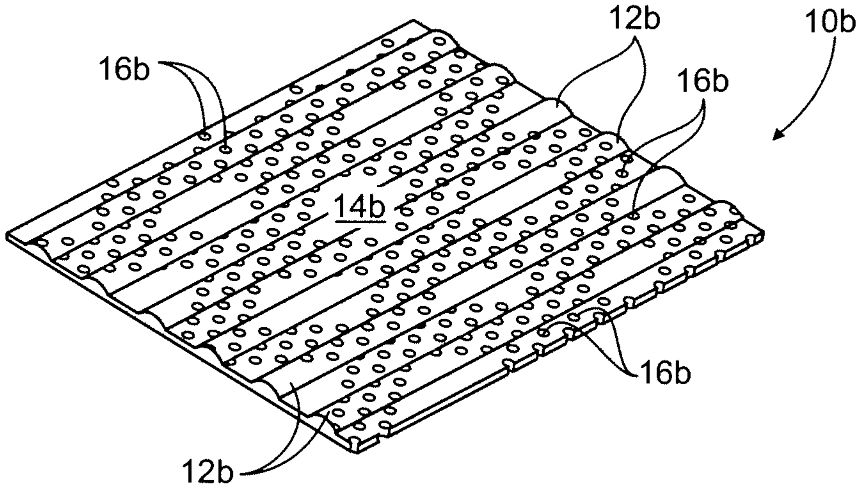

Fig. 8

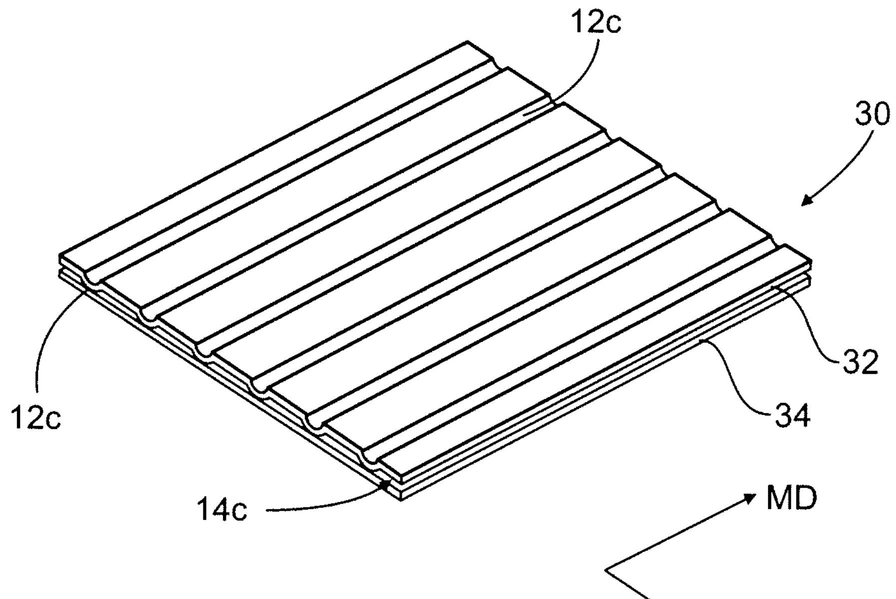

Fig. 9

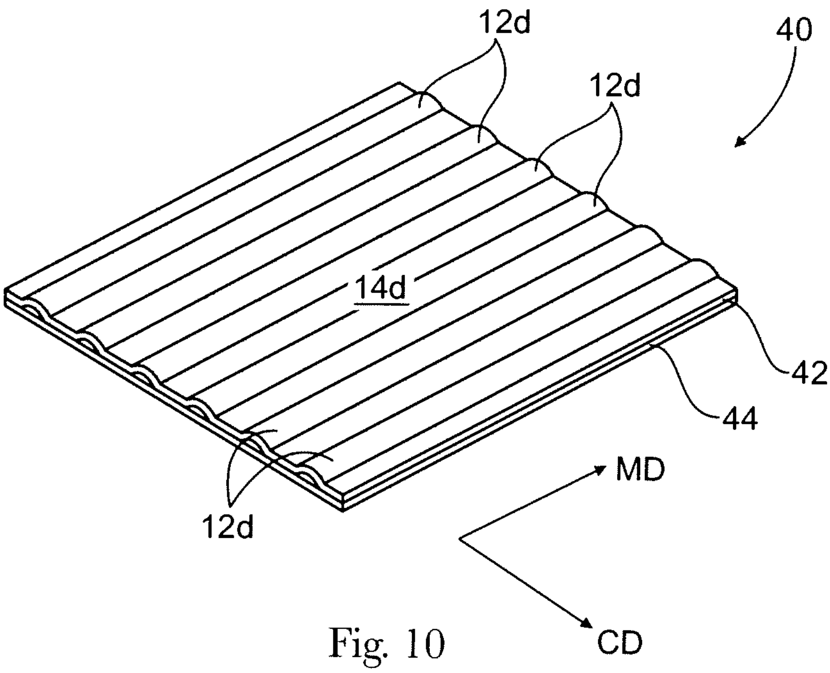

Fig. 10

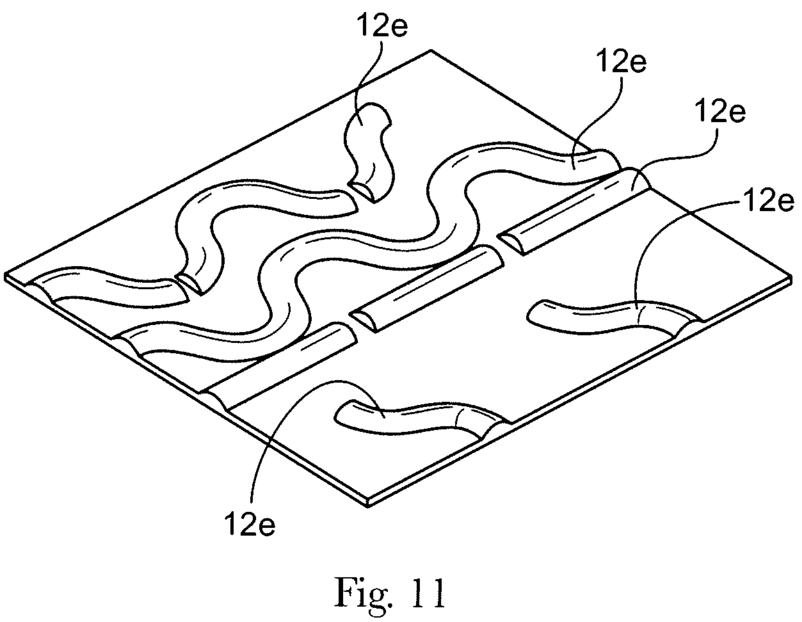

Fig. 11

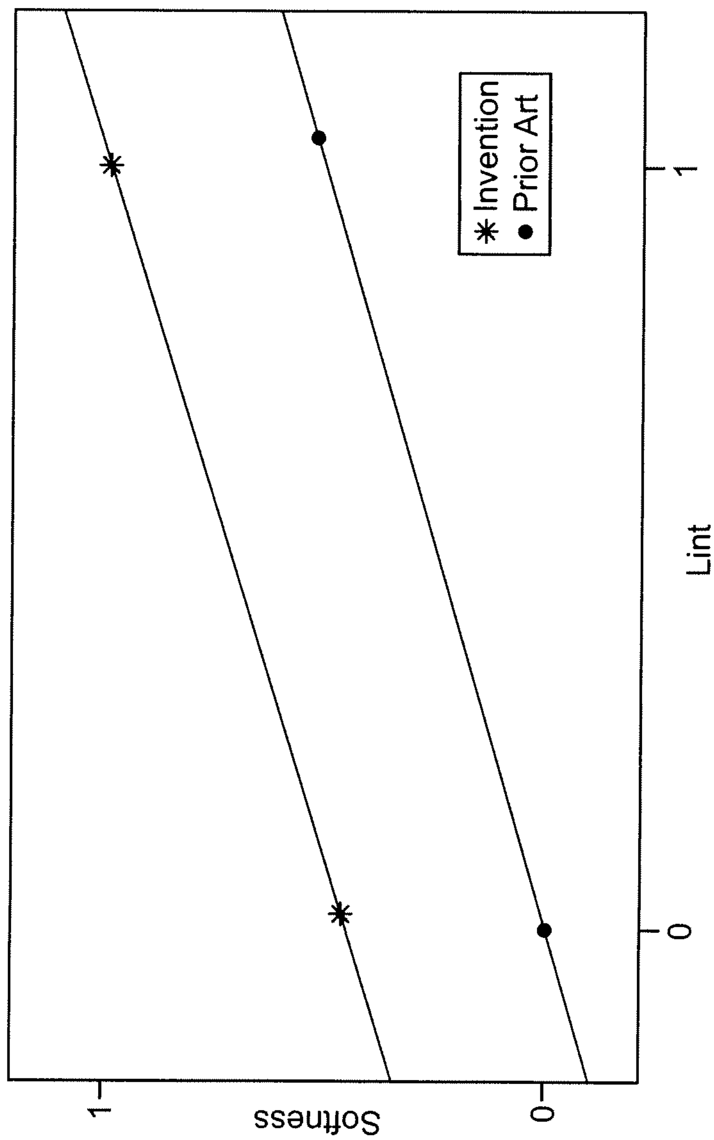

Fig. 12

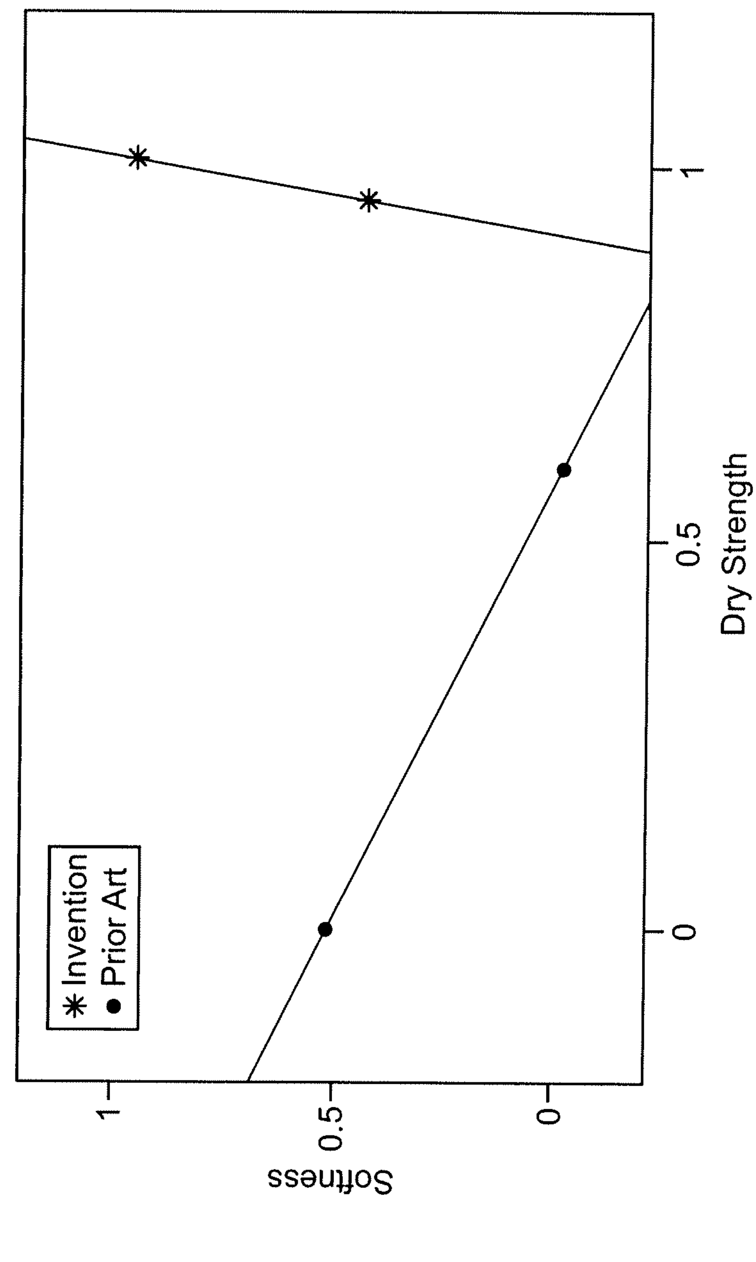

Fig. 13

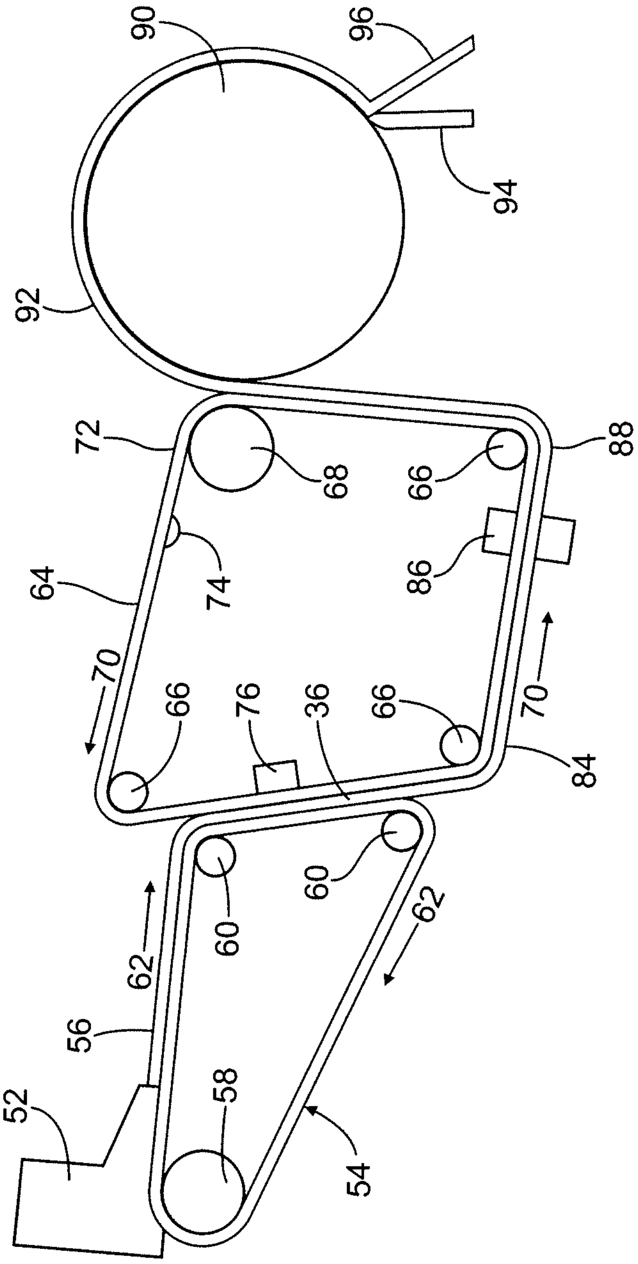

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Fig. 14

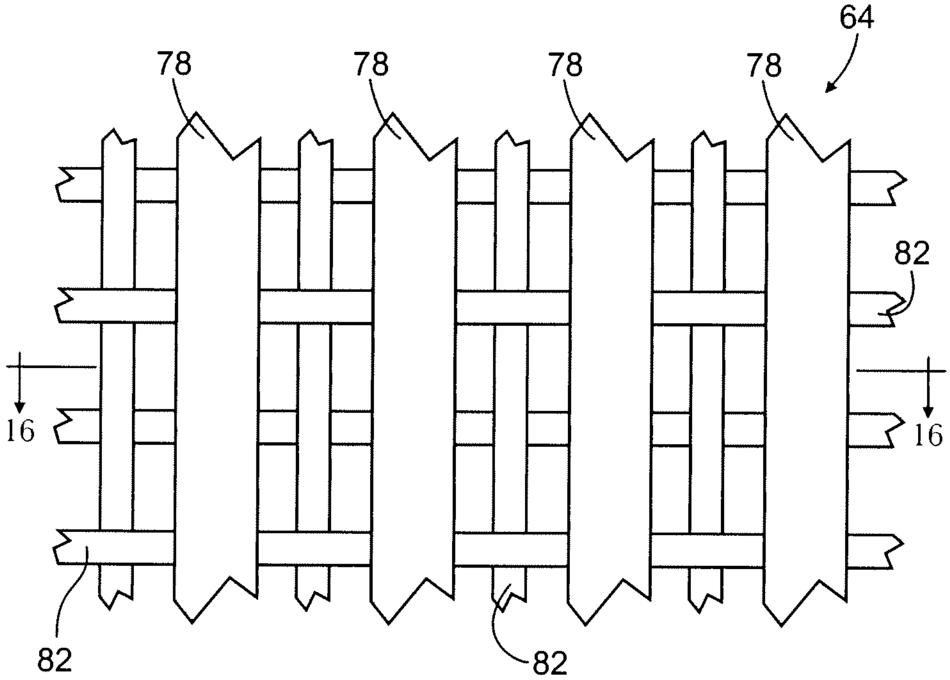

Fig. 15

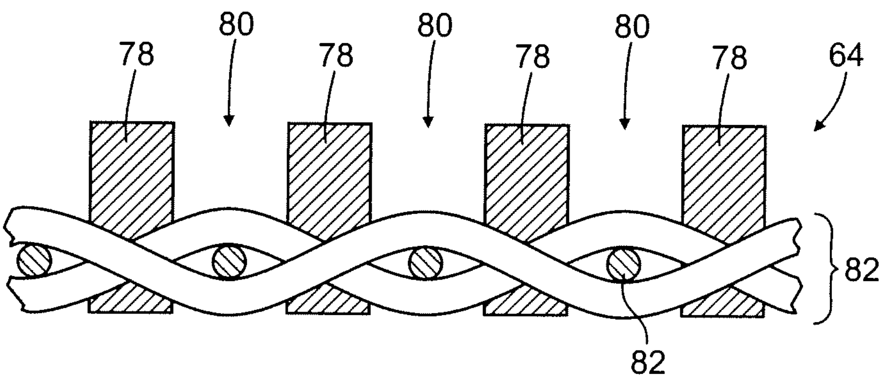

Fig. 16

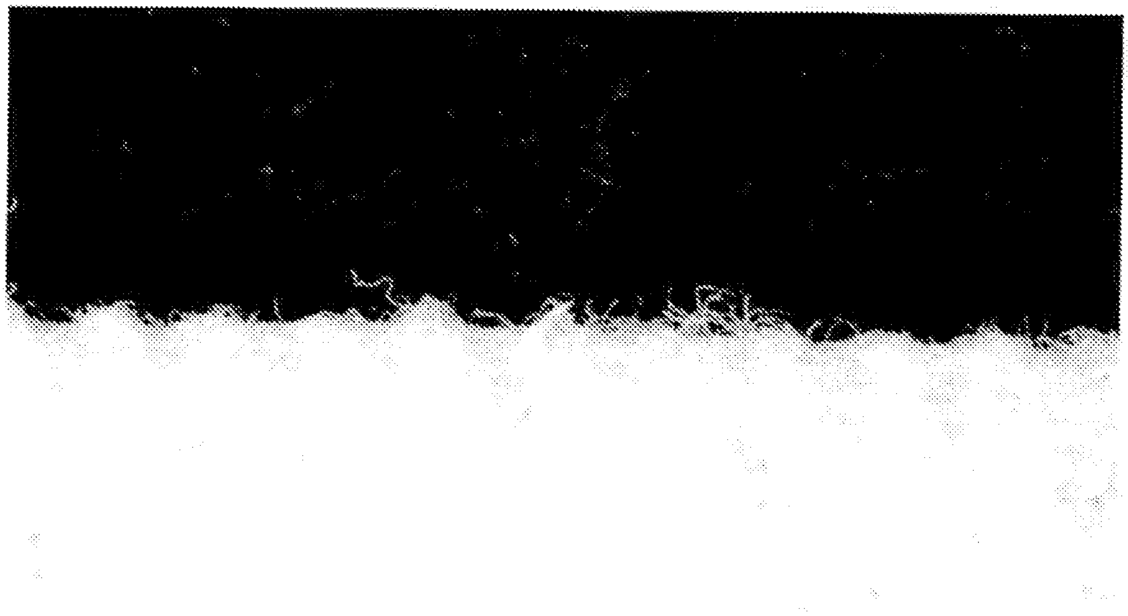

Fig. 17

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/054100

A. CLASSIFICATION OF SUBJECT MATTER
INV. D21H27/00 D21H27/02

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

B. FIELDS SEARCHED

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

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007/070124 A (KIMBERLY CLARK CO [US]; UNDERHILL RICHARD [US]; SONNENBERG JEFF [US];) 21 June 2007 (2007-06-21) page 1, paragraph 1 - paragraph 2 page 5, paragraph 3 - page 7, paragraph 1 page 11, paragraph 4 - page 13, paragraph 3; figures 1,2 -----	1-15
X	WO 2005/068720 A (KIMBERLY CLARK CO [US]; HADA FRANK STEPHEN [US]; BAKKEN ANDREW PETER [) 28 July 2005 (2005-07-28) page 1, line 3 - page 3, line 33 page 6, line 14 - page 7, line 10 page 8, line 21 - page 9, line 12; claims 1-30 -----	1-15
	-/--	

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

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 October 2009	22/10/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Demay, Stéphane

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 4 300 981 A (CARSTENS JERRY E) 17 November 1981 (1981-11-17) column 4, line 33 - column 5, line 3 column 8, line 34 - column 9, line 14 column 18, line 36 - column 19, line 38; figures 31-36; tables Va,Vb -----	1-15
X	EP 0 613 979 A (KIMBERLY CLARK CO [US]) 7 September 1994 (1994-09-07) page 6, line 4 - line 29 page 7, line 51 - page 8, line 10; figures 7-10 -----	1-15
A	US 2004/229067 A1 (BAGGOT JAMES L [US] ET AL) 18 November 2004 (2004-11-18) the whole document -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2009/054100

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