May 15, 1973 C. E. DUNNING 3,733,234

METHOD FOR FORMING AN AIRLAID WEB

Filed May 20, 1971

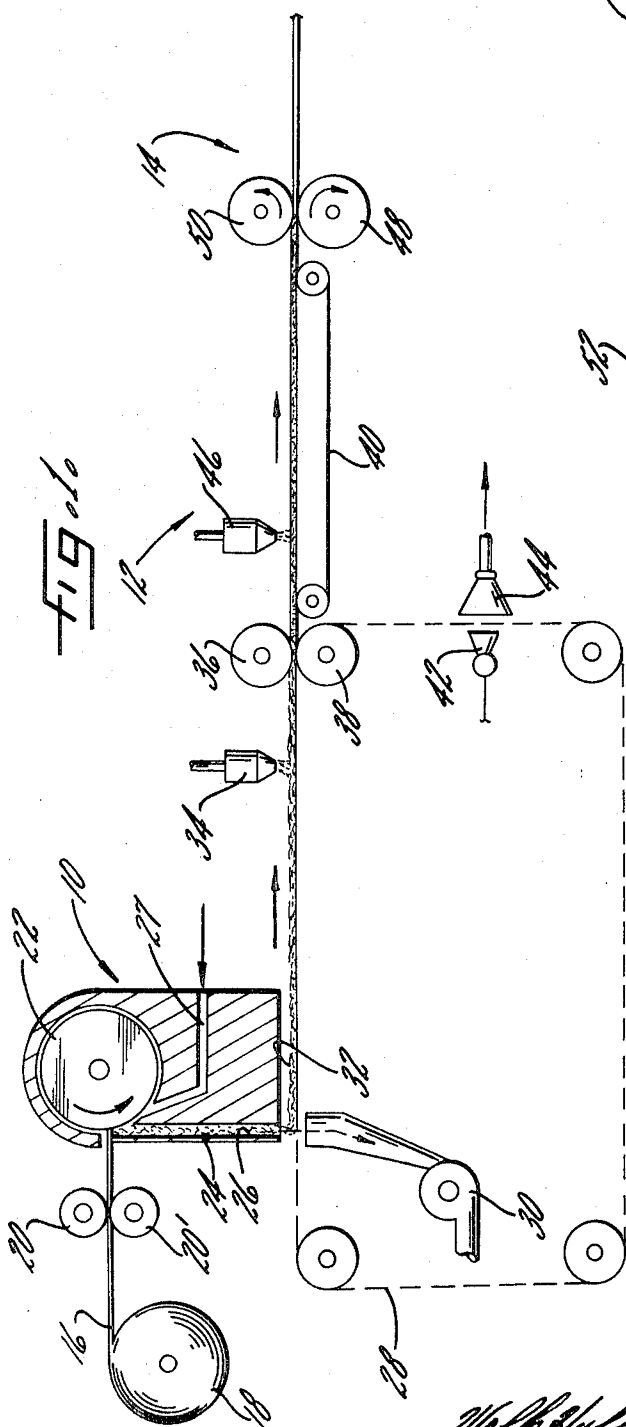

Fig. 1

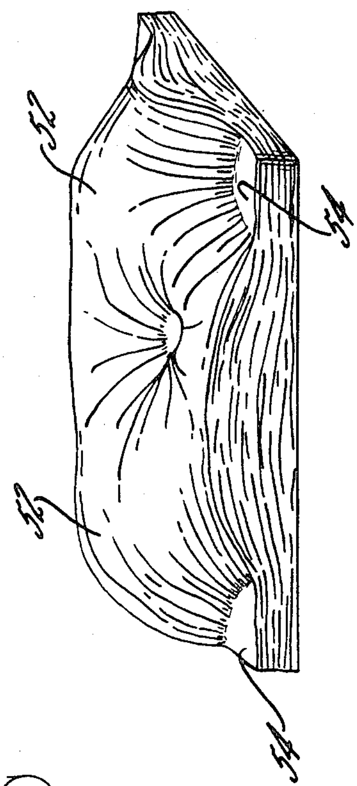

Fig. 2

INVENTOR.
CHARLES E. DUNNING
BY
Wolfe, Hubbard, Leydig, Voit & Osann, Ltd.
ATTORNEYS.

United States Patent Office

3,733,234

Patented May 15, 1973

3,733,234
METHOD FOR FORMING AN AIRLAID WEB

Charles E. Dunning, Neenah, Wis., assignor to Kimberly-Clark Corporation, Neenah, Wis.

Continuation-in-part of abandoned application Ser. No. 882,257, Dec. 4, 1969, which is a continuation-in-part of application Ser. No. 783,877, Dec. 16, 1968. This application May 20, 1971, Ser. No. 145,451
Int. Cl. B31f *1/36*
U.S. Cl. 156—209 9 Claims

ABSTRACT OF THE DISCLOSURE

A method for forming lightweight cellulosic webs useful for tissue and toweling applications comprises air laying a continuum of wood fibers on a foraminous carrier, moisturizing the wood fiber continuum and bonding the continuum with a pair of rolls, at least one having a series of land areas thereon, the rolls forming a nip through which the continuum is passed and adapted to compress the continuum into a pattern of thin, localized bonded fiber zones with zones of substantially unbonded fibers therebetween.

RELATED APPLICATIONS

Dunning and Kellenberger applications, for: "High Speed Method of Forming Airlaid webs" and "Apparatus for Forming Airlaid Webs," filed on even date herewith Ser. Nos. 145,546 and 145,452, respectively.

Dunning, Ser. No. 783,877, filed Dec. 16, 1968, for: "Air Formed Web and Method for Making Such Webs," now abandoned; Ser. No. 882,257, filed Dec. 4, 1969, a continuation-in-part of Ser. No. 783,877. The present application is a continuation-in-part of Ser. No. 882,257.

This invention relates to cellulosic sheet materials and, more particularly, to a method for forming such webs from wood fibers, which webs are characterized by a desirable combination of strength, absorbency and tactile properties.

Conventionally, materials suitable for use as disposable tissue and towel products have been formed on paper-making equipment by water laying a wood pulp fibrous sheet. Conceptually, this equipment is designed so that the configuration of the resulting sheet approaches a two-dimensional structure. This allows continuous operation at high speeds, and such sheets may be formed at speeds of 3,000 to 4,000 feet per minute. Indeed, recent developments have allowed sustained production at speeds of up to 5,000 feet per minute.

Following formation of the sheet, the water is removed either by drying or by a combination of pressing and drying. As water is removed during formation, surface tension forces of very great magnitude develop which press the fibers into contact, resulting in overall hydrogen bonding at substantially all the intersections of the fibers; and a thin, essentially two-dimensional sheet is formed. It is the hydrogen bonds between fibers which provide the sheet strength, and such bonds are produced even in the absence of extensive additional pressing. Due to this overall bonding phenomenon, cellulosic sheets prepared by water-laid methods inherently possess very unfavorable tactile properties (e.g.—harshness, stiffness, low bulk and overall softness) and absorbency for use as sanitary wipes and toweling.

To improve these unfavorable properties, water-laid sheets are typically creped from the dryer roll; i.e.—the paper is scraped from a dryer roll with a doctor blade. Creping reforms the flat sheet into a corrugated-like structure thereby increasing its bulk and simultaneously breaking a significant portion of the fiber bonds, thus artificially improving the tactile and absorbency properties of the

material. But creping raises several problems. It is only effective on low (e.g.—less than about 15 lbs./2880 ft.^{2}) basis weight webs, and higher basis weight webs after creping remain quite stiff and are generally unsatisfactory for uses such as quality facial tissues. Because of this, it is conventional practice to employ at least two plies of creped low basis weight paper sheets for such uses. Only by doing this can a sufficiently bulky product with acceptable softness be prepared. Still further, the detrimental effects of the initial overall bonding in a water-laid paper sheet are not completely overcome.

Sanford et al. (U.S. Pat. No. 3,301,246) proposed to improve the tactile properties of water-laid sheets by thermally pre-drying a sheet to a fiber consistency substantially in excess of that normally applied to the dryer surface of a paper machine and then imprinting the partially dried sheet with a knuckle pattern of an imprinting fabric. The sheet is thereafter dried without disturbing the imprinted knuckle-pattern bonds. While this method may somewhat improve the softness, bulk and absorbency of the resulting sheet, the spaces between the knuckle bonds are still appreciably compacted by the surface-tension forces developed during water removal and considerable fiber bonding occurs. Creping is still essential in order to realize the maximum advantage of the proposed process; and, for many uses, two plies are still necessary.

As will be apparent from the foregoing discussion, conventional paper-making methods utilizing water are geared towards the high speed formation of essentially two-dimensional sheets which inherently possess the inefficient attribute of initial "overbonding" which then necessitates a creping step to partially "debond" the sheet to enhance the tactile properties.

Air forming of wood pulp fibrous webs has been carried out for many years; however, the resulting webs have been used for applications where either little strength is required, such as for absorbent products, i.e., pads, or applications where a certain minimum strength is required but the tactile and absorbency properties are unimportant; i.e.—various specialty papers. U.S. Pats. 2,447,161 to Coghill and 2,810,940 to Mills and British Pat. 1,088,991 illustrate air-forming techniques for such applications.

Indeed, heretofore, it has not been believed that air forming techniques could be advantageously used to prepare cellulosic sheet material that would be sufficiently thin and yet have adequate strength, together with softness and absorbency to serve in applications such as sanitary wipes and toweling.

My copending application, Ser. No. 882,257, herein identified, discloses an aesthetically pleasing web having a combination of strength, absorbency and tactile properties which are suitable for such applications.

It is an object of the present invention to provide a method which is capable of forming such aesthetically pleasing webs having a desirable combination of strength, absorbency and tactile properties.

A further object lies in the provision of method which is adapted to form such webs which may be advantageously employed as a substitute for materials used for conventional tissue and toweling applications. It is a related and more specific object of this invention to provide a method for forming webs with the aforementioned characteristics that can be used as a single ply for such applications.

Yet another object is to provide a method for forming products of the herein described type wherein the desirable combination of properties is achieved without requiring a means for creping.

Other objects and advantages will become apparent as the following description proceeds, taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic view and illustrating apparatus for carrying out the method of the present invention which is capable of forming wood fiber webs having the herein described combination of properties and

FIG. 2 is a schematic view of a portion of a single-ply web formed from the apparatus of FIG. 1 and showing the fluffy mound-like structure of the web.

While the invention is susceptible of various modifications and alternative constructions, there is shown in the drawings and will herein be described in detail the preferred embodiments. It is to be understood, however, that it is not intended to limit the invention to the specific forms disclosed. On the contrary, it is intended to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

Briefly, the method of the present invention includes air laying a continuum of fibers on to a movable foraminous carrier, spraying water on to the continuum to provide the water necessary for bonding and passing the continuum through a nip formed by a pair of rolls, at least one of which has a pattern of land areas thereon. The rolls forms a nip through which the moisturized continuum is passed and subjects the continuum to sufficient compression to form a pattern of thin, localized bonded fiber zones with zones of substantially unbonded fibers therebetween.

Turning now to the drawings, FIG. 1 illustrates an exemplary apparatus for carrying out the method of the present invention which is suitable for forming an airlaid wood fiber web having the herein described properties. In general, the apparatus comprises an air laying station **10** at which the three-dimensional continuum is formed, a spray station **12** at which the continuum is moisturized to provide the necessary water for bonding and a bonding station **14** at which the moisturized continuum is subjected to sufficient pressure to impress a predetermined pattern into the continuum as herein described.

A source of fibers, typically in the form of lightly bonded pulp sheets is provided for the air laying station **10**. Thus, as is shown, a substantially dry wood pulp sheet **16** is unwound from a roll **18** by feed rolls **20, 20'**, powered by means not shown, and forwarded to a conventional picker roll **22** having teeth around its circumference. The picker roll **22** divellicates the pulp sheet into its individual fibers.

The type of wood pulp employed is not particularly critical. Accordingly, pulps having relatively thin walled, long fibers (cedars) to coarse pulps with thick fiber walls (southern pine) can be used. The type of pulp employed will generally be determined by the type of texture desired; the cedar pulps yielding a soft and fluffy texture, while southern pine pulps giving a slightly wooly texture and more body. Thin walled fibers have been found to form a product which is somewhat more flexible and with enhanced softness. The fibers are of a significantly shorter length than ordinary textile fibers and have a length of less than ½ inch. More particularly, the fibers and the pulps described herein have a length distribution of about 1 to 5 mm.

Sheets of pulp prepared by the Kraft process have been found to be particularly useful. However, so long as the fibers separated from the sheet can be subsequently bonded as will hereinafter be described, the manner of the preparation of the pulp is not critical. Particularly, when the present method is operated on a continuous basis, the selection of an appropriate pulp sheet will frequently be influenced by the ease with which the picking can be accomplished. Accordingly, in such instances, low density sheets of unbeaten fibers are generally more desirable. To further facilitate picking, a debonding agent or a mechanical debonding operation can be employed. However, when using a debonding agent, it should only be used in an amount which does not excessively detract from the subsequent bonding which occurs at selected sites in accordance with the use of the present method.

The picker roll **22** may suitably employ picker teeth having a height of about ⅜ inch, a pitch of about ⅜ inch and number about 16 to 24 per square inch of circumferential surface area of the drum. The picker roll separates the pulp sheet into its individual fibers **24** which are conveyed through a forming duct **26** to a foraminous moving carrier or wire **28**. Air from a source, not shown, is passed through chamber **27** and combines with a suction box **30**, which is positioned below the wire **28** and opposite the forming duct **26**, to create a downwardly moving stream of air which assists in collecting the fibers on the moving wire **28** in the form of a three-dimensional continuum **32**. While customary air forming techniques may be used in preparing the continuum, the forming duct illustrated in FIG. 1 is particularly efficient in obtaining an especially suitable continuum. The illustrative duct has a width approximately equal to the height of the picker teeth and is positioned so as to tangentially receive the fibers as they leave the picker. By using a duct with such a width, fiber velocity can be maintained essentially constant throughout the length of the duct. A continuum formed in this manner has exceptionally good cross-width uniformity and is substantially free of fiber floccing. The appropriate size of the forming duct and its arrangement with respect to the picker and the wire are described in detail in copending application, filed on Dec. 4, 1969, by Appel entitled "Pulp Picking Apparatus," now U.S. Pat. No. 3,606,175.

The continuum at this point comprises a fluffy, three-dimensional structure of loose, relatively widely spaced fibers disposed in a random array with respect to the plane of the continuum. In addition, the continuum is highly compressible and may be compacted without using extensive pressure.

Prior to passage to the spray station **12**, the continuum **32** is separated from the forming wire **28**. As shown, a light water spray is applied from a conventional nozzle **34** in order to counteract the static attraction between the continuum and the wire and the continuum is then passed through the nip formed by a calender roll **36** and the tail roll **38** of the wire **28**. This provides the continuum with sufficient integrity so that it may be transferred to a belt **40**. An air shower **42** and a suction box **44** may be employed to clean loose fibers from the wire **28** so as to prevent fiber build-up on the wire and to present a clean surface as the upper course of the wire **28** is presented to the fibers **24**.

Means are next provided to adjust the moisture content of the slightly compacted wood fiber continuum to the level required for bonding. Thus, the continuum **32** is sprayed at the spray station **12** by employing, in the illustrative embodiment, a conventional nozzle **46**. The moisture content should be adjusted to from about 6 to about 45% by the water spray, based upon the wetted weight of the continuum, and generally should be in the range of about 10 to 35%. The use of higher moisture contents will begin to detrimentally affect the tactile and absorbency characteristics of the finished product, presumably due to increased web compaction and bonding in nominally uncompacted spots, while, on the other hand, it is difficult to achieve adequate strength characteristics at lower moisture contents.

Bonding means are then provided to transform the wetted continuum into a coherent web having the herein sought-after properties. To this end, the wetted continuum, after being separated from the belt **40**, is passed through a nip formed by a pair of rolls, at least one of which has a pattern of land areas. The rolls are held in a pressure engagement which is sufficient at the land areas to compress the continuum and bond the fibers together to yield a structure characterized by a regular pattern of closely spaced, deep indentations or thin localized bonded fiber zones with zones of fluffy mounds of substantially unbonded fibers therebetween. The fluffy bonds have been lightly compressed and forced together but remain in their substantially unbonded airlaid state to provide a soft texture and high bulk. Basis weights in the range of from about 5 to about 50 lbs./2880 ft.^{2} may be formed, with a range of from about 10 to 25 lbs./2880 ft.^{2} being suitable for most sanitary wipe and toweling applications. Referring again to FIG. 1, the bonding means comprises a patterned steel roll **48** and a smooth hard roll **50**, which serves as a backup or anvil roll. The thus-formed coherent web may thereafter be treated by reducing the moisture content to the desired degree by means not shown. Any conventional drying apparatus, such as radiant or through-drying, may be employed. Typically, the moisture content of the web will be reduced below about 8% by weight of the wetted web.

To achieve the desired product characteristics, the pattern used in the bonding means, the configuration of the land areas and the pressure involved must be coordinated within certain limits. Thus, the patterned steel roll should have been raised surfaces spaced and with sizes to provide a total bonded area in the resultant web which occupies from about 5 to 40%, generally 8 to 30%, of the web area. Higher bonded areas detrimentally affect absorbency and tactile properties, while insufficient strength is present in webs with lower bonded areas. Typically, the bond areas will be above about 10%. The bond spacing of the raised surfaces should also be less than about the average length of the wood fibers employed in forming the web. Furthermore, in order to enhance web strength uniformity, a regularly repeating bonding pattern is preferred. Bond area frequencies of about 10 to 40 per inch across both dimensions of the web are useful.

In order to achieve sufficient bonding in the above-described apparatus, the bonding means employed must be capable of being positioned in pressure engagement so that the pressure exerted on an individual bond area should be at least 2,000 p.s.i. To a large extent, the maximum pressure is determined by the yield point of the respective nip rolls. In this respect, an anvil roll must be used which has characteristics which will allow development of the necessary pressure on the individual bond areas. While the anvil roll does not have to be as hard as soft steel, the Young's Modulus and Poisson's ratio must be such that point pressures in the necessary range may be developed. Thus, a material such as nylon which has a Young's Modulus of 3.5 times 10^5 p.s.i. and a Poisson's ratio of 0.4 may be used; but materials with such values which indicate that they are significantly softer than nylon would be unsatisfactory. Such materials would tend to flatten out in the nip areas and decrease the amount of pressure that can be developed below that which is necessary. On the other hand, when smooth metallic materials are used as the anvil roll, it is desirable to use materials softer than the bonding roll to avoid fracturing the points of the bonding roll.

The configuration of the raised portions on the patterned roll is not thought to be particularly critical although, to a limited extent, the configuration can influence directional strength characteristics. Thus, circular shapes may be used since these provide a maximum surface area for bonding and may also minimize wear on the points. However, other geometric shapes such as diamonds and the like may also be used. The raised points should have a flat surface and the height of the points and the slopes from the roll surface should be coordinated with the pressure conditions involved to minimize undue compaction of the continuum between raised surfaces but should allow use without undue breakage of the points. Raised portion heights of 0.015 to 0.030 are generally useful.

The novel product constructed in accordance with the method of the present invention is illustrated in FIG. 2. Thus, as is shown, the product is characterized by fluffy mounds of fibers with a substantially random orientation **52** which are interrupted by a pattern of closely spaced, deep indentations or bonded areas **54**. Since the fiber orientation in the basic plane of the web is quite random, the web exhibits substantially isotropic tensile strength. It is believed that certain product attributes of the web are present because of the relationship of the thin, localized bonded areas to the fluffy, mound regions. More particularly, the pressure in the nip is sufficient to compact the continuum in the bonded areas to less than about 40% of the height of the fluffy, mound regions and usually less than about 20%. The fibers emerging from the bonded areas and extending toward the mound areas thus have a substantial orientation out of the basic plane of the web, i.e.—a Z-direction orientation. This aspect, together with the frequency of the bond areas, provides a structure which may be visualized as a "spring" structure. Thus, a considerable number of fibers may be viewed as starting in the bond area, emerging out of such area into the mound region with a substantial Z-direction orientation and then returning to the plane of the web in an adjacent bond area. Individual fibers can accordingly be visualized as being anchored at both ends in one plane and therebetween being bent considerably out of the plane to provide a stable structure which has spring or resilience when compressive force is applied in a direction perpendicular to the plane of the web. This structure is believed to contribute significantly to the desirable tactile properties of the web. It is further hypothesized that the "spring" structure may at least partially be responsible for the surprisingly high rate at which such webs are able to absorb liquids due to the existence of a unique capillary structure in and between the fluffy mound regions. This spring-like mound structure may serve to at least in part prevent collapse of the web on initial web wetting.

Stated another way, some of the fibers in the continuum are rearranged into at least partially a Z-direction orientation as a result of the action of the high pressure areas in the nip of engaging and pressing the fibers and producing the compacted zones. The thus-rearranged fibers together with other fibers having a Z-direction orientation in their airlaid state provide a significant Z-direction fiber component in the mound areas and a web of overall substantially uniform thickness with the compacted and bonded zones providing coherency and strength. The high pressure areas are achieved by passing the continuum through a nip formed by hard-surfaced rolls with at least one of the rolls having a pattern of lands. The rolls are maintained in sufficient pressure engagement to compress the web zones opposite the lands to form the compacted and bonded zones with the uniformly relieved low pressure areas occurring in the remainder of the continuum.

As hereinbefore noted, the bonding may compact the fluffy, mound regions. Thus, for example, the wetted continuum on the belt **40** may have a height of about 20 to 50 mils, and the fluffy, mound regions, after passing through the bonding nip, may have a height of about 8 to 20 mils. The fibers in the mound regions are, however, still in substantially unbonded form. Furthermore, it should be appreciated that the thin, localized bonded areas may be somewhat "bowed" and the side of the web adjacent the anvil roll may not have as pronounced a mound structure as the surface contacted by the patterned roll **48**. Appropriate selection of the rolls in the bonding assembly can provide a web with the desired relationship between the structure of the two surfaces.

The following examples illustrate the preparation of webs using the method of the present invention and described with reference to FIG. 1. Table I gives the general process conditions for preparing these webs. The pulp feed to the picker **22** consisted of sheets of northern soft wood (mixture of black spruce, jack pine, and balsam fir) bleached Kraft pulp having a basis weight of 70 lbs. per 2880 ft.^{2} and a density of 0.6 gram/cc. The compacting rolls **36** were operated at a pressure of 12 lbs. per lineal inch and a smooth nylon roll **50** was used. The webs of the examples were dried by radiant heating after passing through the bonding nip. The bonding roll **48** was steel with diamond-shaped embossing points arranged in a 60°

triangle-type pattern. The foraminous wire 28 was operated at 27 feet per minute. Table I shows the results:

TABLE I

Example	I	II	III
Basis weight, lbs./2,880 ft.²	11	13	17
Moisture content prior to rolls 32	8	8	8
Moisture content prior to bonding (percent)	20	20	24
Bonding pressure, lbs./lineal inch	149	188	149
Bonding pattern (points per inch)	19	25	19
Total bonded area, percent of web	10	10	10
Suggested single ply end use	(1)	(1)	(1)

[1] Bathroom tissue.

Thus, as has been seen, the present invention provides a method suitable for forming a fluffy, three dimensional airlaid continuum and for transforming that continuum into a coherent web by appropriate spraying and bonding. The method fashions a web which has satisfactory strength for sanitary wipe and toweling applications yet retains, to the extent possible, the bulk or loft of the three-dimensional continuum so that the resulting web is characterized by highly advantageous tactile properties. Similarly, the pattern of bond areas impressed on the continuum by the bonding is believed to be at least partially responsible for the desirable absorbency properties of the web.

I claim as my invention:

1. The process of forming a web suitable for single-ply uncreped sanitary wipes or toweling from paper-making wood fibers comprising the steps of

(a) random laying a web of dry fibers on a moving foraminous carrier to a basis weight of 5 to 50 pounds per 2880 square feet.

(b) moistening the dry web while it is on the belt with water in an amount more than 6% and less than 45% of the wetted weight,

(c) passing the web through a nip formed by hard-surfaced rolls with one of the rolls having a pattern of lands constituting a minor portion of the roll area with the lands spaced less than an average fiber length distant from each other,

(d) maintaining the rolls in sufficient pressure engagement to compress the web zones opposite the lands at a pressure of several thousand pounds per square inch and form hydrogen bonds between the fiber portions in said zones,

(e) and drying the fiber mounds defined between the compressed zones in the absence of pressure to leave the fiber portions in the mounds substantially unbonded with a height several times that of the web thickness in the bond zones.

2. The process of claim 1 wherein the web of dry fibers has a basis weight of 10 to 25 pounds per 2880 square feet.

3. The process of claim 1 wherein the dry web is moistened with water in an amount of from about 10 to 35% of the wetted weight.

4. The process of claim 1 wherein the rolls are maintained in sufficient pressure engagement to compress the web zones opposite the lands at a pressure of at least 2,000 pounds per square inch and to leave the fiber portions in the mounds substantially unbonded with a height of at least 2.5 times that of the web thickness in the bond zones.

5. The process of claim 4 wherein the rolls are maintained in sufficient pressure engagement to leave the fiber portions in the mounds with a height of a least 5 times that of the web thickness in the bond zones.

6. A method for making a lightweight cellulosic web characterized by a three-dimensional continuum of fibers of paper making length interrupted by a pattern of bonded fiber zones from an airlaid three-dimensional fiber continuum having a basis weight of 5 to 50 pounds per 2880 square feet which comprises spraying water onto the surface of the continuum, to provide a moisture content of from 6 to 45% by weight of the wetted web, passing the continuum through a nip in which a pattern of similarly shaped high pressure areas acting on the continuum press and compact the fibers in said areas and are surrounded by uniformly relieved low pressure areas, the combination of said high pressure areas and relieved areas and moisture which penetrates the continuum from the wetted surface producing thin, localized, compacted bonded fiber zones spaced less than an average fiber length distant from each other in the continuum surrounded by uncompacted fluffy mounds of fibers of substantially uniform height, some of the fibers in the continuum being rearranged into at least partially a Z-direction orientation as a result of the action of the high pressure areas in the nip of engaging and pressing the fibers and producing the compacted zones, together with other fibers having a Z-direction orientation in their airlaid state, providing a significant Z-direction fiber component in the mound areas and a web of overall substantially uniform thickness, said compacted and bonded zones providing coherency and strength.

7. The method of claim 6 wherein the continuum is passed through a nip formed by hard-surfaced rolls with at least one of the rolls having a pattern of lands and wherein the rolls are maintained in sufficient pressure engagement to provide high pressure areas of at least 2,000 pounds per square inch to compress the web zones opposite the lands with the remainder of the continuum being in uniformly relieved low pressure areas.

8. The method of claim 6 wherein the high pressure areas act on the continuum at a frequency of from about 10 to 40 per inch across both dimensions of the continuum and are sized to form compacted and bonded zones in from about 5 to 40% of the area of the continuum.

9. The method of claim 8 wherein the compacted and bonded zones comprise at least 10% of the area of the continuum.

References Cited

UNITED STATES PATENTS

2,955,641 10/1960 Burgeni .... 156—219

WILLIAM A. POWELL, Primary Examiner

J. J. BELL, Assistant Examiner

U.S. Cl. X.R.

156—62.2, 290, 306; 161—124, 148, 150