

[54] METHOD AND APPARATUS FOR FORMING A NONWOVEN FIBROUS WEB

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[58] Field of Search. 156/62.2, 62.6, 62.8, 156/289, 291, 305, 381, 382, 496, 497, 548, 578, 181, 543, 555, 229; 19/155, 161 R; 425/81, 82, 83, 115; 264/88

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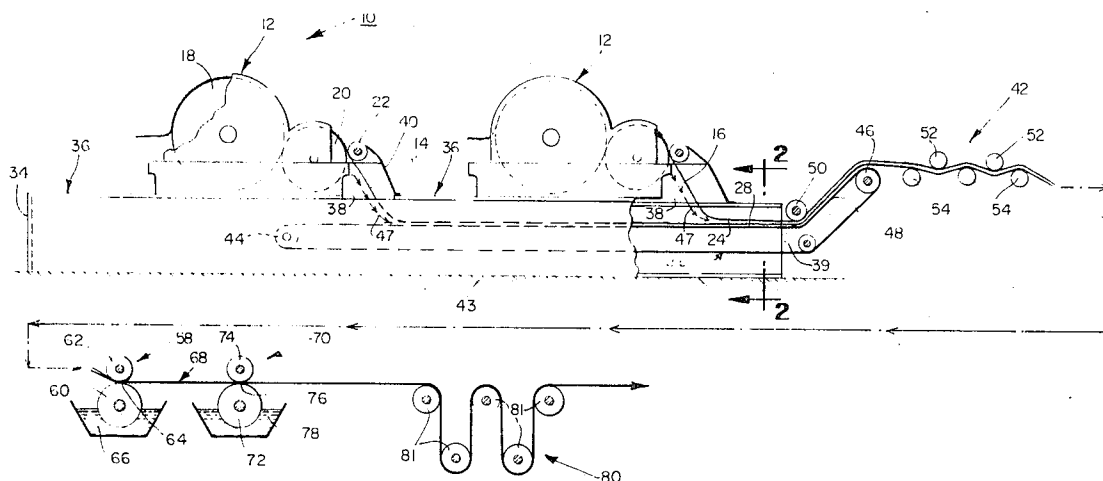
[57] ABSTRACT

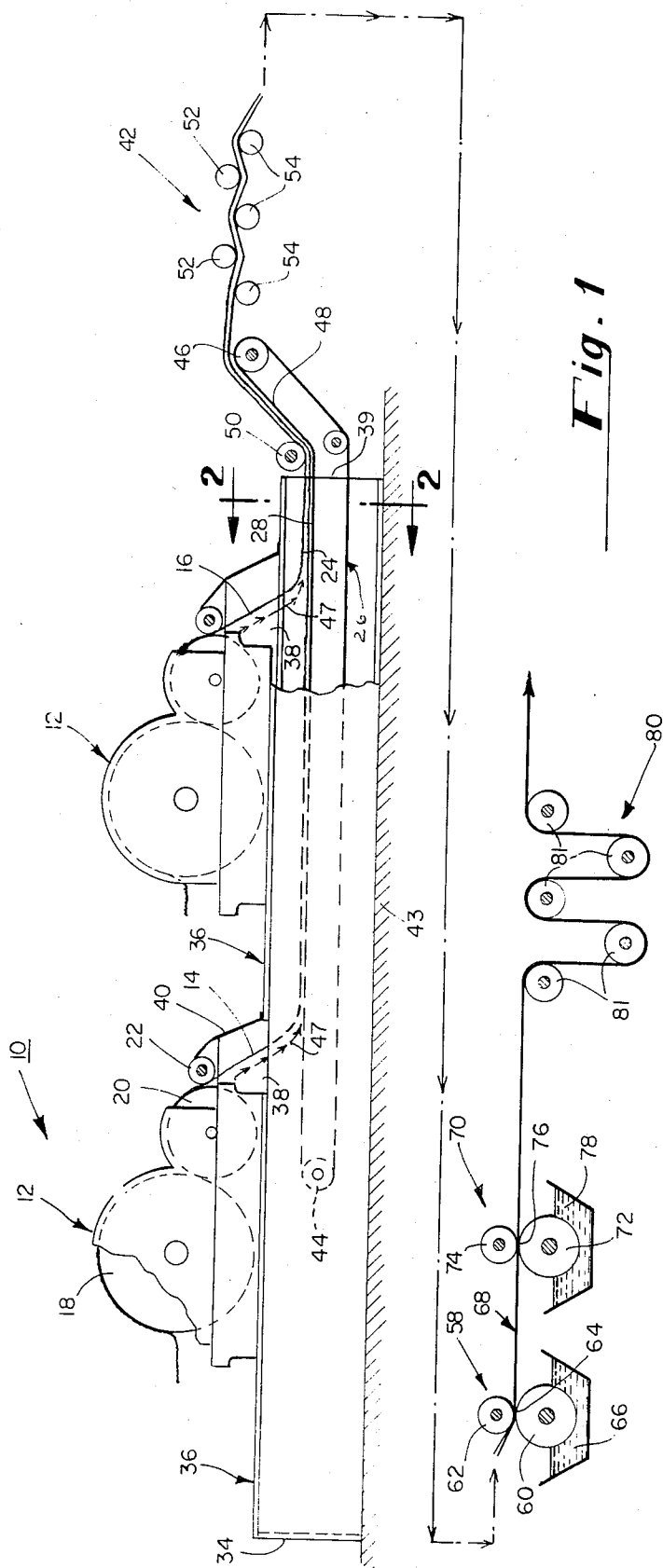
A method of forming a nonwoven fibrous web from multiple laps of staple fibers, the major proportion of fibers within each lap being substantially oriented in one direction. Laps of the staple fibers are fed into overlying relationship with the major proportion of oriented fibers in each lap disposed in the same direction. Air is entrapped between adjacent laps as they

are fed into overlying relationship to create an air barrier between adjacent overlying laps. The overlying laps are spread transversely of the direction in which the major proportion of fibers are oriented, and fibers within overlying laps are reoriented transversely within the plane of the laps out of the direction in which the major proportion of fibers are oriented while maintaining the air barrier between the adjacent overlying laps. The laps are pressed together after the lap spreading and fiber reorienting steps to form a unitary nonwoven fibrous web and fibers of the unitary nonwoven fibrous web are then bonded together.

An apparatus for forming a nonwoven fibrous web from multiple laps of staple fibers, the major proportion of fibers within each lap being substantially oriented in one direction. Lap forming means for forming the laps of staple fibers and for generating air currents. A lap-confining channel is defined in part by a lower, air-impervious conveyor belt, and a shield encloses the downstream end of each lap forming means and defines an enclosed flow path from the lap forming means to the lap-confining channel. The enclosed flow path permits the laps of staple fibers to be directed into overlying relationship with each other within the lap-confining channel and aids in establishing laminar flow of the air currents into the lap-confining channel to define air barriers between adjacent laps, and between the conveyor belt and lower lap. The conveyor belt feeds the overlying laps to a spreading and reorienting means disposed downstream of the lap forming means for spreading the overlying laps transversely of their direction of feed and for reorienting fibers within overlying laps transversely within the plane of respective laps out of the direction in which the major proportion of fibers are oriented while maintaining the air barrier between the adjacent overlying laps. Calendering means disposed downstream of the spreading and reorienting means for pressing the overlying laps together to form a unitary nonwoven fibrous web, and bonding means disposed downstream of the calendering means for bonding together fibers of the unitary nonwoven fibrous web.

23 Claims, 5 Drawing Figures





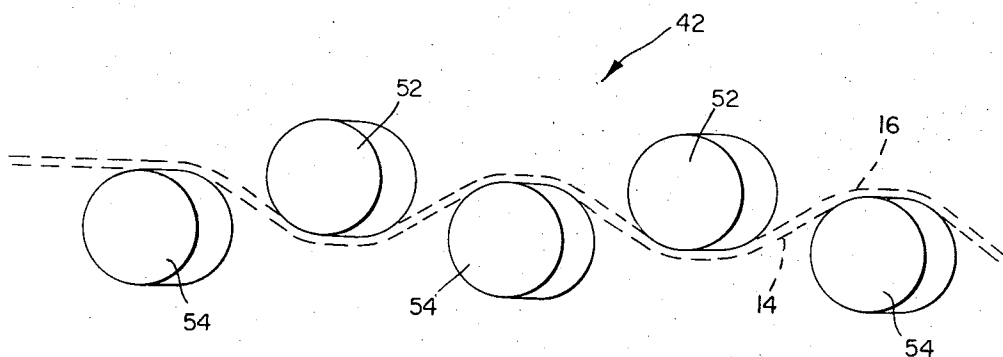


Fig. 3

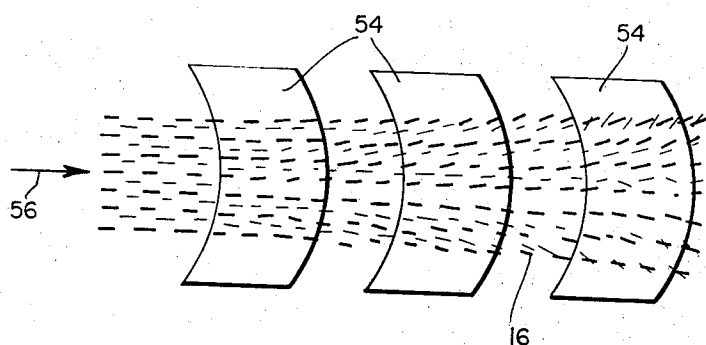


Fig. 4

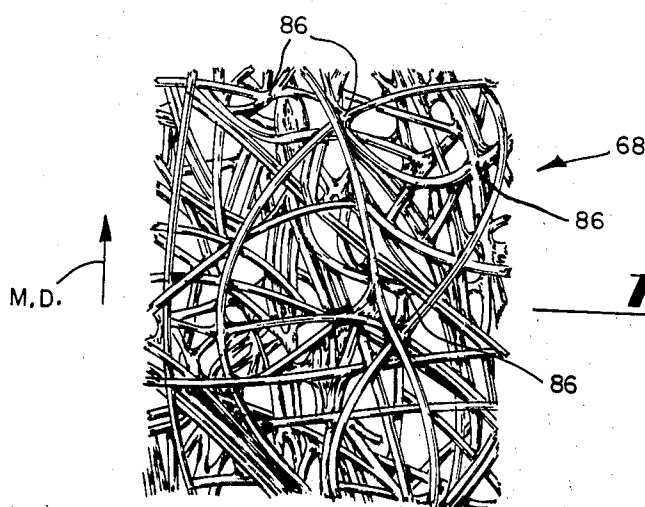


Fig. 5

METHOD AND APPARATUS FOR FORMING A NONWOVEN FIBROUS WEB

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method and apparatus for forming a nonwoven fibrous web, and more particularly to a method and apparatus for forming a nonwoven fibrous web from multiple laps of staple fibers, the major proportion of said staple fibers within each lap being substantially oriented in one direction.

2. Description of the Prior Art

Nonwoven fibrous webs for use as a cover material for absorbent components in sanitary products, such as disposable diapers, sanitary napkins and the like, have been manufactured conventionally from multiple laps of loosely associated staple fibers, the major proportion of fibers within each lap being oriented, or parallelized in the "machine-direction," i.e., in the direction in which the laps move continuously from the lap-forming apparatus. Such laps have been produced continuously by conventional card machines and have been formed into a nonwoven fibrous web by feeding the laps into overlying relationship onto a slatted, or other air pervious conveyor; calendering, or pressing the laps together to form a unitary nonwoven fibrous web; spreading the web transverse to the machine-direction and bonding fibers together in the spread web.

The above-described method of web formation produces a nonwoven web in which the major proportion of fibers are highly oriented, or parallelized in the machine-direction. Such a web has an exceptionally high machine-direction tensile strength, but is normally quite weak in the cross-machine-direction. These nonwoven webs tend to tear when subjected to cross-direction stresses during the use of products incorporating such webs in their construction.

The cross-machine-direction tensile strength of a nonwoven fibrous web can be increased to an acceptable level by cross lapping individual laps of staple fibers such that the oriented, or parallelized fibers in some of the laps are aligned in the cross-machine-direction. Forming a web by cross lapping individual laps is considerably slower, and therefore more costly, than forming a web by superimposing individual laps with their oriented, or parallelized fibers disposed in the same direction.

The cross-machine-direction tensile strength of a nonwoven fibrous web can be improved by utilizing large amounts of adhesive to bond fibers together in the web. Utilizing large amounts of adhesive increases the cost of such nonwoven webs. Furthermore, large amounts of adhesive will seriously impair the "hand" of the nonwoven web, which is undesirable in most products in which such nonwoven webs are incorporated.

Prior art apparatus for forming nonwoven fibrous webs from multiple laps of loosely associated staple fibers, the major proportion of which are oriented, or parallelized in the machine-direction, have employed slatted, or air pervious conveyors upon which the laps are directed into overlying relationship with each other. These air pervious conveyors have been maintained open to permit the dissipation of air currents created by the high speed rotation of elements of conventional web forming machines, such as the high speed rotation of a card roll in a conventional card ma-

chine. In these prior art apparatus, turbulent air currents have been created at web forming speeds exceeding 100 feet per minute. These turbulent air currents roll along the loosely associated fibers in the overlying laps and tend to disassociate the fibers within the laps from each other to destroy the integrity of these laps and thereby prevent the formation of an acceptable nonwoven fibrous web. The use of an air-impervious conveyor in prior art apparatus is somewhat effective in minimizing air turbulence through the laps of staple fibers; however, the air impervious conveyor interacts with the fibers in the laps to create static charges on the fibers of the laps at high web forming speeds to prevent uniform web formation. Therefore, the prior art apparatus are speed-limited by the creation of turbulent air flow and/or static charges.

Prior art apparatus in which spreading means, such as Mount Hope rolls, are utilized to spread the nonwoven fibrous web in the cross-machine-direction, have employed a press, or calender section prior to the spreading means to firmly press the overlying laps into engagement with each other to form a unitary nonwoven fibrous web prior to the spreading operation. It has been thought that a nonwoven web having a substantially uniform fiber distribution could only be produced if the individual laps comprising the nonwoven web were pressed into a unitary structure prior to the spreading operation. This method of web spreading has provided for substantially uniform fiber distribution; however, the degree of fiber reorientation transversely out of the machine-direction of the web has been so minimal as to only slightly increase the cross-machine-direction strength of the web. A nonwoven fibrous web formed in apparatus in which a press, or calender section is disposed upstream of the spreading section has an undesirable low cross-machine-direction tensile strength, and tends to tear when subjected to cross-machine-direction stresses during normal use of products in which the nonwoven web is incorporated.

In order to improve the cross-machine-direction tensile strength of a nonwoven fibrous web, prior art apparatus have employed spray, or print bonding stations for applying a large amount of adhesive to bond fibers together in the nonwoven web. The bonded area has accounted for over 33 percent, and in many instances as much as 100 percent of the total area of the nonwoven web. A nonwoven web formed with large amounts of adhesive has a poor "hand" which is unsuitable for use in many end products. In addition, the cost of manufacturing a nonwoven web is directly related to the amount of adhesive utilized, i.e., the greater the amount of adhesive utilized, the more expensive the cost of manufacture. Therefore, it is important to utilize as little adhesive as possible in obtaining the desired web characteristics in order to minimize manufacturing costs.

SUMMARY OF THE INVENTION

This invention relates to a method and apparatus for forming a nonwoven web from multiple laps of loosely associated staple fibers, the major proportion of the fibers within each lap being predominately oriented, or parallelized in one direction. The method of this invention comprises the steps of feeding the laps of staple fiber into overlying relationship with the major proportion of fibers in each lap disposed in the same direction, entrapping air between adjacent overlying laps to cre-

ate an air barrier between adjacent overlying laps for preventing extensive clinging together of fibers between adjacent laps, reorienting fibers within overlying laps transversely within the plane of the laps out of the direction in which the major proportion of fibers are oriented while maintaining the air barrier between said adjacent overlying laps, pressing the laps together after fiber reorientation to form a unitary nonwoven fibrous web and bonding together fibers of said unitary nonwoven fibrous web.

Applicants unexpectedly have found that by maintaining an air barrier between the overlying laps of staple fibers during the fiber reorienting step, a greater degree of fiber reorientation can be achieved than when the laps are pressed into a unitary web prior to the fiber reorienting step. This greater degree of fiber reorientation results in a nonwoven web having a higher cross-machine-direction tensile strength than has heretofore been achieved in webs of corresponding basis weight formed from multiple laps of staple fibers, the major proportion of which are substantially oriented in one direction.

Applicants are not certain of the mechanism responsible for the greater degree of fiber reorientation resulting from the method of their invention. However, applicants believe that since the fibers within each of the overlying laps are loosely associated during the reorienting step (by virtue of being substantially uncompressed into a closely associated, interlocked condition prior to fiber reorientation) they are more easily reoriented transversely out of the direction in which the major proportion of fibers are originally disposed than are the fibers in a lap, or web, in which the fibers are closely associated and interlocked. Furthermore, the air barrier between adjacent overlying laps tends to maintain said laps separate from each other, whereby fibers within overlying laps are reoriented separately from each other. This separate reorientation of fibers is believed to be partly responsible for the greater degree of fiber reorientation achieved according to the method of this invention.

In the preferred embodiment of this invention, the fiber reorienting step is carried out by directing the overlying laps between upper and lower sets of bowed rolls sold under the trademark "Mount Hope" by Mount Hope Manufacturing Company of Tauton, Massachusetts. One of the sets of rolls is offset in the machine-direction relative to the other set. The upper rolls reorient fibers of one of the outer laps transversely out of the machine-direction in successive stages, and the lower rolls reorient fibers of the other of the outer laps transversely out of the machine-direction in successive stages which alternate with the successive stages of fiber reorientation of said one of the outer laps. When more than two laps are disposed in overlying relationship the greatest degree of fiber reorientation occurs in the outer laps since the outer laps are engaged directly by the sets of upper and lower rolls.

In the most preferred embodiment of this invention one of the upper and lower sets of rolls includes more rolls than the other set to achieve different degrees of fiber reorientation in the outer laps adjacent each set of rolls. This different degree of fiber reorientation results in a relative reorientation between the fibers in the outer laps which results in the formation of a more isotropic web than if the fibers in the overlying laps are reoriented to the same degree.

The method of this invention eliminates the need for large amounts of adhesive to bond together fibers in the nonwoven fibrous web to achieve the requisite cross-machine-direction strength in said web. Preferably, the nonwoven fibrous web is print bonded in a discrete pattern such that the bonded area of the web accounts for less than 25 percent of the entire area thereof. Preferably, the bonded area is 10 percent or less of the entire area of said web. In the preferred embodiment of this invention in which the web is print bonded, the laps are wet pressed together to prevent the web from wrapping up about the print bonding roll. If the nonwoven web is spray banded, a dry press, or calender operation can be utilized instead of the wet press required when print bonding is utilized since no wrap-up problem exists.

Apparatus of this invention in which the method of this invention is carried out comprises at least two conventional lap forming means, such as carding machines, for forming laps of staple fibers, the major proportion of which are predominately oriented in the machine-direction. The apparatus includes a lap-confining channel which is open at a downstream end thereof, and a shield which encloses a downstream end of each lap forming means and which extends to the lap-confining channel to establish an enclosed flow path from the lap forming means to the lap-confining channel. The enclosed flow path permits the laps of staple fibers to be directed into overlying relationship with each other within the lap-confining channel and aids in establishing laminar flow into the lap-confining channel of air currents generated by the lap forming means. The air currents are generated by high speed rotation of elements of the lap forming means, such as the high speed rotation of a card roll in a conventional carding machine.

The lap-confining channel is defined in part by a lower, air-impervious conveyor belt, and the air currents establish an air barrier between adjacent overlying laps, and between the conveyor belt and the lower lap. The conveyor belt directs said overlying laps through the downstream open end of said lap-confining channel, and the air barrier between the lower lap and conveyor belt prevents the build up of static charges on the fibers of the laps of staple fibers as the laps are being directed through the lap-confining channel. The generation of static charges can destroy the integrity of the laps of staple fibers, and thereby prevent the formation of an acceptable nonwoven web. Since the conveyor belt is air-impervious, the air is not permitted to flow in a turbulent manner through the upper delivery run of the conveyor belt supporting said laps. The lap-confining channel is completed by air-impervious side members disposed closely to opposed side margins of the conveyor belt, and by a back member and an upper closure. The side members prevent a substantial flow of air transversely around side margins of the conveyor, the back member prevents air flow in an upstream direction through the lap-confining channel and the upper closure prevents air from escaping upwardly from the lap-confining channel. The lap-confining channel functions to maintain laminar air flow in a downstream direction to establish the air barriers between the adjacent overlying laps and between the lower lap and the conveyor belt.

The upper closure can include a continuous air-impervious member having entrance openings formed therethrough to permit the formed laps to be directed

onto the air-impervious conveyor. Alternatively, the upper closure may comprise separate and discrete air-impervious members which are spaced from each other in the machine-direction to provide entrance openings therebetween through which the formed laps can be directed onto the air-impervious conveyor.

The apparatus of this invention includes lap spreading and fiber reorienting means disposed downstream of the lap forming means for spreading the laps in the cross-machine-direction and for reorienting fibers predominantly aligned in the machine-direction transversely within the plane of the laps out of said machine-direction while maintaining the air barrier between adjacent overlying laps. The apparatus of this invention further includes calendering means disposed downstream of the spreading and reorienting means for pressing the adjacent overlying laps together to form a unitary nonwoven fibrous web, and bonding means disposed downstream of the calendering means for bonding together fibers of said unitary nonwoven fibrous web. A drying section is disposed downstream of the bonding means for drying the web in the event it has been moistened in the calendering or bonding operation, and for curing and/or setting the bonding agent.

One extremely important feature of this invention is that the web forming apparatus must be operated at high web-forming speeds, i.e., over 200 feet per minute, to provide and/or maintain the requisite air barrier between the adjacent laps to permit the degree of fiber reorientation achieved according to the method of this invention. Therefore, the present invention is not speed-limited by the creation of turbulent air flow, and in fact requires the formation of a web at a greater speed than has heretofore been achievable with prior art apparatus. Applicants have found that enhanced cross-machine-direction tensile strength is not achieved in a web forming operation in which the web is formed at approximately 200 feet per minute or less. Applicants believe that web forming speeds of 200 feet per minute or less direct an insufficient volume of air into the lap-confining channel to form an air barrier between adjacent overlying laps and/or the air tends to escape from the region between adjacent overlying laps prior to the fiber reorienting step.

It is an object of this invention to form a nonwoven web with enhanced cross-machine-direction tensile strength from multiple laps of staple fibers, the major proportion of which initially are oriented predominantly in the machine-direction.

It is a further object of this invention to form a nonwoven web with enhanced cross-machine-direction tensile strength at high speeds from multiple laps of loosely associated staple fibers, the major proportion of which initially are oriented predominantly in the machine-direction.

It is a further object of this invention to form a nonwoven web having enhanced cross-machine-direction tensile strengths without utilizing large amounts of adhesive.

Other objects and advantages of this invention will become apparent upon reading the detailed description which follows, taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic side elevation view of an apparatus according to this invention for carrying out the method of this invention;

FIG. 2 is a sectional view along line 2—2 of FIG. 1;

FIG. 3 is an enlarged side elevation view of the lap spreading and fiber reorienting section utilized in this invention;

FIG. 4 is a schematic plan view showing the lap spreading and fiber reorienting of a nonwoven lap of staple fibers according to the method of this invention; and

FIG. 5 is a plan view of a nonwoven fibrous web formed according to the method of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

Referring to FIG. 1, an apparatus 10 of this invention for forming nonwoven fibrous webs includes conventional lap forming means, such as carding machines 12, for forming laps 14 and 16 of loosely associated staple fibers, for major proportion of which are predominantly oriented in the machine direction of lap formation. Each carding machine 12 includes a card roll 18 having a plurality of pins or wire points (not shown) disposed about the periphery thereof for combining fibers from a feed mat of staple fibers to orient a major proportion of said fibers in the machine-direction, and a doffing roll 20 for collecting and removing the oriented fibers from the card roll in lap form. Suitable lap removing means 22; such as that which is sold under the trademark "Doffmaster" by John D. Hollingsworth on Wheels, Inc. of Greenville, South Carolina; is disposed adjacent the doffing roll 20 of each carding machine 12 for removing the laps from the doffing roll and for directing said laps into overlying relationship within a lap-confining channel 24 onto an air-impervious continuous conveyor belt 26.

Referring to FIGS. 1 and 2, the lap-confining channel 24 is defined by an upper delivery run 28 of the continuous conveyor belt 26; a pair of transversely spaced, substantially U-shaped side members 30, each of which has a central web portion 32 disposed closely to a side margin of the upper delivery run 28 of the conveyor belt 26; a back member 34 and an upper closure. The upper closure preferably is defined by discrete members 36 which are spaced apart in the machine-direction to define entrance openings 38 through which the fibrous laps 14 and 16 are directed into the lap-confining channel 24. The lap-confining channel 24 has an open downstream end 39 through which the superimposed fibrous laps 14 and 16 are directed by the conveyor belt 26. Each side member 30 preferably has a lower returned leg 41 which is secured to a floor 43 by any suitable securing means (not shown), and an upper returned leg 45 to which the closure members 36 are secured by any suitable securing means (not shown).

The individual lap 14 and 16 are directed from the carding machines 12 through the entrance openings 38 by the Doffmaster 22 into overlying relationship within the lap-confining channel 24. High speed rotation of the card roll 20 drives air into the lap-confining channel 24, as is shown schematically by arrows 47 to form an air barrier between the upper delivery run 28 of the conveyor belt 26 and the lower lap 14, and also between the fibrous laps 14 and 16. The air barrier between the delivery run of the conveyor belt and the lower lap 14 prevents the build up of static charges as the laps are fed by the conveyor. The air barrier between fibrous laps 14 and 16 prevents extensive clinging together of fibers in the lap 14 with fibers in its adja-

cent lap 16. The lap-confining channel 24 aids in establishing laminar air flow in the air barrier regions by confining the flow path of said air to a substantially downstream direction.

The air-impervious conveyor belt 26 prevents air from passing through the upper, delivery run 28 thereof. If air were permitted to flow through the upper run of the conveyor belt, a turbulent, swirling air flow would result at high web forming speeds which would destroy the integrity of the fibrous laps 14 and 16. The side members 30 prevent a significant volume of air flow transversely around side margins of the upper delivery run 28 of the conveyor belt 26, and thereby further aids in directing the air flow in a substantially downstream direction through the lap-confining channel. The back member 34 and the upper closure members 36 further aid in maintaining substantially laminar air flow in the downstream direction through the lap-confining channel 26 by preventing air from escaping through the upstream end and top of said lap-confining channel.

An air-impervious shield 40 is disposed adjacent the downstream end of each carding machine 12 and encloses the front and sides of the machine to define a substantially enclosed flow path from each carding machine to a respective entrance opening 38 to aid in establishing laminar air flow from each carding machine 12 into the lap-confining channel 24, and to assure that each lap will be directed through a corresponding entrance opening.

The overlying fibrous laps 14 and 16, with the air barrier maintained therebetween, is directed by the conveyor belt 26 to a lap spreading and fiber reorienting section 42. The continuous air-impervious conveyor belt 26 is disposed about spaced rolls 44 and 46, at least one of which is driven to convey the overlying fibrous laps 14 and 16, with the air barrier entrapped therebetween, through the downstream end 39 of the lap-confining channel 24. Due to the dimensional requirements of the various components of the apparatus 10, the upper delivery run 28 of the continuous conveyor belt 26 is provided with an upwardly directed section 48 disposed in a downstream direction for feeding the overlying laps into the lap spreading and fiber reorienting section 42. The upwardly directed section 48 is established by a conveyor diverting roll 50 which does not apply excessive pressure to the superimposed fibrous laps 14 and 16 to dissipate the air barrier between said laps.

The fibrous laps 14 and 16 are formed and are fed to the spreading and reorienting section 42 at a sufficiently fast rate to establish an air barrier between the adjacent overlying laps 14 and 16, and between the lower lap 14 and delivery run 28 of the conveyor belt within the lap-confining channel 24, and to maintain the air barrier between said laps at the spreading and reorienting section 42. The exact speed limits required to establish and maintain the air barriers have not been positively determined; however, applicants have observed that web forming speeds below 200 feet per minute are too low, and that web forming speeds in the range of from about 250 feet per minute to about 425 feet per minute have resulted in the establishment of an air barrier between adjacent overlying laps 14 and 16 and the maintenance of said air barrier between said overlying laps as they are fed into the spreading and reorienting section 44. Applicants have not achieved web

forming speeds over 425 feet per minute due to limitations in the presently existing equipment; however, applicants believe that the advantages of the present invention will be achieved, and in fact enhanced, by higher operating speeds.

Referring to FIG. 3, the lap spreading and fiber reorienting section 42 includes an upper set of bowed rolls 52 and a lower set of bowed rolls 54, both of which preferably are of the type sold under the trademark "Mount Hope" by Mount Hope Machinery Company of Tauton, Massachusetts. In the preferred embodiment of this invention, the upper rolls 52 are spaced in the machine-direction from the lower rolls 54, and all rolls are positively driven. By spacing the rolls in the above-described manner the laps 14 and 16 will be spread in successive stages, and fibers within each lap will be transversely reoriented out of the machine-direction in successive stages; the successive stages of lap spreading and fiber reorienting of lap 14 alternating with the successive stages of lap spreading and fiber reorienting of lap 16. To further explain, when a region of the upper fibrous lap 14 is being worked by an upper roll 52, an underlying region of the lower fibrous lap 16 is not being worked by a lower roll 54. When a region of the lower fibrous lap 16 is being worked by a lower roll 54, an underlying region of the upper fibrous lap 14 is not being worked by an upper roll 52. Although the spreading and reorienting section 42 is shown as comprising two upper rolls 52 and three lower rolls 54, the number of upper and lower rolls can be varied depending upon the degree of spreading and/or fiber reorientation that is desired in the finished nonwoven fibrous web. In the preferred embodiment of this invention more rolls are provided in one set than the other set to thereby work the fibers in laps adjacent each set of rolls to different degrees, and thereby achieve different degrees of fiber reorientation within the laps adjacent the two sets of rolls. In this manner a more isotropic web, i.e., a web having more uniform strength characteristics in all directions, is formed than if the laps adjacent each set of rolls were worked to the same degree.

Referring to FIG. 4, the mechanism of lap spreading and fiber reorientation is shown schematically. The fibrous lap 16 enters the upstream end of the spreading section 42 with the fibers predominately oriented in the machine-direction. As the lap 16 traverses the lower rolls 54 in the direction indicated by arrow 56, the lap is expanded in a cross-machine-direction, and fibers which were initially predominately oriented in the machine-direction are transversely reoriented out of the machine-direction within the plane of the fibrous lap 16. Since the fibers in the laps 14 and 16 remain substantially uncompacted as they are fed into the spreading section 62, they remain loosely associated with respect to each other and therefore are believed to be more easily reoriented than the fibers within a lap, or a nonwoven web which has been compacted to cause the fibers to become closely associated and mechanically interlocked with each other prior to the spreading operation. Moreover, the maintenance of an air barrier between the superimposed laps 14 and 16 permits the laps to be spread, and the fibers therein to be reoriented, independently of each other, which also is believed to contribute to a greater degree of fiber reorientation than has heretofore been achieved by spreading a nonwoven web formed by compacting superimposed laps of staple fibers prior to the spreading operation.

Referring to FIG. 1, the laps 14 and 16 are passed from the lap spreading and fiber reorienting section 42 through a wet calender station 58. The wet calender station 58 includes opposed, driven rolls 60 and 62 defining a nip 64 therebetween. The lower roll 60 passes through a wetting solution 66, and conveys the wetting solution to the nip 64 to accomplish wet pressing of the laps 14 and 16 in said nip to form a unitary nonwoven fibrous web 68. The nonwoven fibrous web 68 is then directed through a bonding station 70 which is preferably a print bonding station comprising opposed, driven rolls 72 and 74 defining a nip 76 therebetween. The lower roll 72 passes through an adhesive solution 78, and conveys said solution into the nip 76 to bond fibers together in the unitary nonwoven fibrous web 68. Preferably, the lower print bonding roll 72 is patterned to pick up adhesive in discrete patterns to thereby form discrete bonded areas in the nonwoven fibrous web 68 which accounts for less than 25 percent of the total area of said web, and preferably accounts for 10 percent or less of the total area of said web. The wet calendaring operation prior to the bonding operation prevents wrap-up of the nonwoven fibrous web 68 around either of the bonding rolls 72, 74. If a spray bonding station is utilized to bond together fibers of the nonwoven web 68, the wet calender station 58 may be replaced by a dry calender station, since there is no wrap-up problem encountered at a spray bonding station.

A dryer station 80 is disposed downstream of the bonding station 70, and preferably is comprised of a plurality of driven can dryers 81. The can dryers 81 dry the web to remove moisture therefrom, and also serve as the means for setting and/or curing the adhesive. The dried web is fed from the can dryers onto a supply roll (not shown) for storage and/or subsequent use.

Referring to FIG. 5, the nonwoven fibrous web 68 has a substantially large number of fibers oriented in the cross-machine-direction. Fibers within the nonwoven web are bonded together in discrete areas 86. The nonwoven web shown in FIG. 5 is comprised of staple rayon fibers, 1-½ denier, 2 inches long, and is shown as it appears at a magnification of 100x in a scanning electron microscope.

The staple fibers utilized in forming the nonwoven webs according to the method of this invention preferably have a length exceeding one-half inch, and include such fibers as rayon, polyolefins, polyamides and polyester.

Any suitable wetting solution can be utilized at the wet calender station 58. For example, the wetting solution can include water with less than 1 percent of a wetting agent, such as DIANOL, sold by Quaker Chemical Company of Conshohocken, Pennsylvania.

Many different adhesives can be utilized to bond together fibers of the nonwoven web, and the specific type of adhesive utilized does not form a part of the present invention. Lattices, such as polyvinyl acetate, copolymer emulsions and acrylic lattices have been satisfactorily utilized in the present invention.

As a result of the present invention, nonwoven fibrous webs can be manufactured with a lower basis weight than prior art nonwoven webs, while obtaining the same, or higher cross-machine-direction tensile strengths. This fact is illustrated by the following examples;

EXAMPLE I

Nonwoven webs were formed at a speed of 100 feet per minute from two laps of carded rayon fibers having a length of 2 inches and a denier of 1-½. These laps were superimposed upon each other, pressed into a substantially unitary nonwoven web, passed through a spreading section comprising two upper Mount Hope rolls and three lower Mount Hope rolls, passed through a wet press section and passed through a print bonding station to bond together fibers of the nonwoven web. The bonded web was then passed over a series of can dryers to dry the web and cure the adhesive. Nonwoven webs formed according to the above method had a basis weight of approximately 12.9 pounds per ream, and had an average cross-machine-direction tensile strength of 5.9 ounces per inch based on 5,000 tested samples.

EXAMPLE II

Nonwoven webs were formed from two laps of carded rayon fibers having a length of two inches and a denier of 1-½ according to the method of Example I, with the exception that the webs were formed at speeds exceeding 250 feet per minute within a lap-confining channel as described heretofore, and the laps were passed through the spreading section without prior compression into a unitary nonwoven web. The wetting solution and adhesive, including the types, amounts and pattern, were identical to those utilized in Example I. The nonwoven webs formed according to this method had a basis weight of approximately 11 pounds per ream, and an average cross-machine-direction tensile strength of 7.1 ounces per inch based on 9,000 tested samples.

The above examples clearly indicate the benefits obtained according to the method of this invention.

What is claimed is:

1. A method for forming a nonwoven fibrous web from multiple laps of staple fibers at a speed in excess of 200 feet per minute, the major proportion of said staple fibers within each lap being substantially oriented in one direction, said method comprising the steps of:

- A. feeding the laps of staple fibers in a downstream direction into overlying relationship with each other with said major proportion of fibers in each lap disposed in the same direction;
- B. establishing laminar air flow in said downstream direction between adjacent overlying laps to create an air barrier between said adjacent overlying laps for preventing extensive clinging together of fibers between said adjacent overlying laps;
- C. reorienting fibers within the plane of overlying laps transversely out of said one direction while maintaining said air barrier between said adjacent overlying laps;
- D. pressing said laps together to form a unitary nonwoven fibrous web; and
- E. bonding together fibers of said unitary nonwoven fibrous web.

2. The method according to claim 1, including spreading said overlying laps in a direction transverse to said one direction simultaneously with reorienting fibers within the plane of said overlying laps.

3. A method according to claim 1, wherein the fibers within one of said overlying laps is reoriented to a dif-

ferent degree than the fibers within another of said overlying laps.

4. The method to claim 1, wherein the fibers within said overlying laps are reoriented by reorienting the fibers within said overlying laps in successive stages, the successive stages of fiber reorientation in one of said overlying laps alternating with the successive stages of fiber reorientation in another of said overlying laps.

5. The method according to claim 1, including wet pressing said laps together to form said unitary nonwoven fibrous web, print bonding together fibers of said unitary nonwoven fibrous web and drying said nonwoven fibrous web after print bonding.

6. The method according to claim 5, including print bonding together fibers of said unitary nonwoven fibrous web in a discrete, discontinuous pattern of bonded areas separated by unbonded areas.

7. The method according to claim 6, wherein said bonded areas comprises less than 25 percent of the entire area of said nonwoven fibrous web.

8. A method for forming a nonwoven fibrous web from multiple laps of staple fibers at a speed in excess of 200 feet per minute, the major proportion of said staple fibers within each lap being substantially oriented in one direction, said method comprising the steps of:

- A. directing the laps in a downstream direction into overlying relationship within a lap-confining channel with said major proportion of fibers in each lap being disposed in the same direction;
- B. establishing laminar air flow in said downstream direction between adjacent overlying laps within said lap-confining channel to form an air barrier between said adjacent overlying laps;
- C. feeding said adjacent overlying laps with the air barrier therebetween in said one direction between upper and lower sets of reorienting rolls, the rolls in one set being spaced in said one direction from the rolls of the other set for reorienting fibers within the plane of overlying laps transversely out of said one direction in successive stages;
- D. pressing said adjacent overlying laps together to form a unitary nonwoven fibrous web; and
- E. bonding together fibers of said unitary nonwoven fibrous web.

9. The method according to claim 8, including spreading each of said overlying laps in a direction transverse to said one direction simultaneously with reorienting fibers within the plane of said overlying laps.

10. The method according to claim 8, wherein the number of rolls in the upper set differs from the number of rolls in the lower set for reorienting the fibers within overlying laps to different degrees.

11. The method according to claim 8, including wet pressing said adjacent overlying laps together to form said unitary nonwoven fibrous web, print bonding together fibers of said unitary nonwoven fibrous web and drying said nonwoven fibrous web after bonding.

12. The method according to claim 11, including print bonding together fibers of said unitary nonwoven fibrous web in a discrete discontinuous pattern of bonded areas separated by unbonded areas.

13. The method according to claim 12, wherein said bonded areas comprise less than 25 percent of the entire area of said nonwoven fibrous web.

14. An apparatus for forming a nonwoven fibrous web from multiple laps of staple fibers at a speed in ex-

cess of 200 feet per minute, the major proportion of said staple fibers within each lap being substantially oriented in one direction, said apparatus comprising:

- A. lap forming means for forming said laps of oriented staple fibers and for generating air currents;
- B. a lap-confining channel being defined by a lower air-impervious conveyor, opposed air-impervious side members disposed closely to side margins of said air-impervious conveyor, a back member and an upper closure, said lap-confining channel being open at a downstream end thereof;
- C. shield means for defining an enclosed flow path between said lap forming means and said lap-confining channel, said laps and air currents being directed through said enclosed flow path into said lap-confining channel to form overlying laps with an air barrier between adjacent overlying laps and between the conveyor and its adjacent lap;
- D. means for driving said air-impervious conveyor for conveying said overlying laps in a downstream direction through the open downstream end of said lap-confining channel;
- E. fiber reorienting means disposed downstream of said lap forming means for reorienting fibers within the plane of overlying laps transversely out of said one direction while maintaining said air barrier between said adjacent overlying laps;
- F. calendering means disposed downstream of said fiber reorienting means for pressing said adjacent overlying laps together to form a unitary nonwoven fibrous web; and
- G. bonding means disposed downstream of said calendering means for bonding together fibers of said unitary nonwoven fibrous web.

15. The apparatus according to claim 14, wherein said calendering means is a wet press calendering means for wetting said adjacent overlying laps and pressing said adjacent overlying laps together to form a unitary nonwoven fibrous web, and drying means disposed downstream of said bonding means for drying the bonded, nonwoven fibrous web.

16. The apparatus according to claim 14, wherein said bonding means comprises opposed rolls, at least one of said opposed rolls having a discrete pattern therein for bonding together fibers of said unitary nonwoven fibrous web in a pattern corresponding to said discrete pattern.

17. The apparatus according to claim 14, wherein said upper closure of said lap-confining channel has entrance openings defined therethrough, said laps being directed through said enclosed flow channel and said entrance openings into said lap-confining channel.

18. A method for forming a nonwoven fibrous web from multiple laps of staple fibers at a speed in excess of 200 feet per minute, said method comprising the steps of:

- a. feeding the laps in a downstream direction into overlying relationship within a lap-confining channel with the major proportion of the fibers in each lap substantially oriented in the feed direction;
- b. establishing laminar air flow in said downstream direction within the lap-confining channel simultaneously with the feeding of the laps into said lap-confining channel;
- c. feeding the overlying laps in said downstream direction between upper and lower sets of reorienting rolls prior to pressing said overlying laps to-

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gether, the rolls in one set being spaced in the downstream direction from the rolls in the other set for reorienting fibers within the plane of overlying laps in successive stages transversely out of said downstream direction;

d. pressing said adjacent overlying laps together after reorientation to form a unitary nonwoven fibrous web; and

e. bonding together fibers of said unitary nonwoven fibrous web.

19. The method according to claim 18, including spreading each of said overlying laps in a direction transverse to said downstream direction simultaneously with the reorienting of the fibers within the plane of said overlying laps.

20. The method according to claim 18, wherein the

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number of rolls in the upper set differs from the number of rolls in the lower set for reorienting the fibers within overlying laps to different degrees.

21. The method according to claim 18, including wet pressing said adjacent overlying laps together to form said unitary nonwoven fibrous web, print bonding together said fibers of said unitary nonwoven fibrous web and drying said nonwoven fibrous web after bonding.

22. The method according to claim 21, including print bonding together fibers of said unitary nonwoven fibrous web in a discrete discontinuous pattern of bonded areas separated by unbonded areas.

23. The method according to claim 22, wherein said bonded areas comprise less than 25 percent of the entire area of said nonwoven fibrous web.

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