NONWOVEN FABRIC AND PROCESS FOR PREPARING

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15 Claims

ABSTRACT OF THE DISCLOSURE

Nonwoven fabrics are prepared by crosslaying an open network of fibril-interconnected substantially parallel continuous monofilaments with a similar network at an angle of 20–89° and bonding the same.

This invention relates to novel nonwoven fabrics and to a process for the preparation thereof.

Nonwoven fabrics are textile fabrics which are neither woven, spun, nor made by conventional wool felting processes. Rather, they consist of an aggregation of staple textile fibers interlocked to form a mat-like structure. Typical applications where these fabrics find utility include filter cloths, clothing insulation, carpet backing, gasket material, blankets, dollies, driers, cloth surgical dressings, pennants, inner-soles for shoes, and many others.

Several processes are presently known for preparation of nonwoven fabrics. In one such process, the fibers are slurried in water or a similar inert liquid, the slurry is spread uniformly on a flat surface, the inert liquid is drained off and the web is dried under pressure to form a loosely associated web of randomly arranged fibers. In another process, dry fibers are laid on a solid flat surface, as a conveyor, by mechanical means such as, e.g., a carding machine. This dry process can be used to lay down the fibers in either a random or oriented arrangement. To impart strength and cohesion to the fiber mass, a bonding step is carried out by chemical or mechanical means. A thorough discussion of the preparation of nonwoven fabrics as presently practiced can be found in "Nonwoven Fabrics" by F. M. Buresh—Reinhold Publishing Co., New York, N.Y., 1962.

It is the object of this invention to provide a new and improved nonwoven fabric and a method of preparing the same. The new and improved nonwoven fabric is comprised of a plurality of substantially parallel, low denier, continuous monofilament strands of a thermoplastic polymer in the warp direction, having a plurality of substantially similar strands cross-laid on at least one surface thereof and making an angle between about 20° and 89° with said warp direction strands, said cross-laid strands being of the same or different thermoplastic composition and being bonded to said warp direction yarns at their crossover points therewith, said fabric having a weight between about 0.1 and 15 ounces per square yard.

Preferably, the denier of the filaments will be between about 1.5 and 20 and more preferably no higher than about 15. Higher denier filaments can be employed in the process, but fabrics resulting therefrom may be less desirable as they will be too stiff for most applications where nonwoven fabrics are employed.

Nonwoven fabrics meeting the above description are unique in the art in that they are made up entirely of low denier, continuous monofilament yarns in both the warp and cross direction. This factor results in several property advantages over prior art nonwovens whether based on staple fibers, continuous monofilament yarns or spun yarns. For example, these fabrics have greater covering power per unit weight than would a similar fabric prepared from a multifilament yarn, due to individual monofilaments being situated side by side rather than in bundles as would be the case with a continuous filament yarn or with synthetic staple fibers. For this same reason, one can prepare a stronger product using this technique since each individual filament can be bonded at the cross-over point rather than bonding just a relatively few filaments on the outside of a yarn bundle. Thus, there can be a greater number of bonds per unit area as well as per unit weight than are normally possible with other nonwoven types. The strength of such fabrics is also improved by the presence in both the warp and filling directions of continuous filaments which are inherently stronger than spun yarns or staple fibers of the same denier.

One further advantage of these fabrics accruing from the use of low denier monofilament strands is that a very pliable product can be formed—i.e., one having a high degree of drape.

The unique nonwoven fabrics according to this invention can be prepared by a lamination process employing warp and cross-laying beams of substantially parallel continuous monofilament strands. In brief, this process comprises laying down a warp of substantially parallel, low denier continuous monofilament strands and cross-laying said warp at an angle between about 20° and 89° with a plurality of similar substantially parallel continuous monofilament strands, and bonding said strands at their points of crossover with one another. In a preferred embodiment of the process of the invention, the substantially parallel continuous monofilament strands are the product resulting from fibrillation of striated film.

The concept of fibrillating a striated film has recently been introduced into the art as a method of preparing low denier monofilaments. The striations in such a film provide precisely defined lines of weakness in a direction substantially parallel to the longitudinal axis of the film, i.e., parallel to the direction of orientation. When this film is subjected to mechanical working to cause splitting, such splitting is confined to the thin areas and the thick areas can be separated as continuous filaments. These films can be either oriented parallel to the striations or unoriented when they are subjected to fibrillation. Whether or not they are oriented is determined by the intended end use.

The mechanical working can be sufficient to effect a complete fibrillation of the film. In such a case, the product is a plurality of individual, unconnected, parallel continuous monofilaments.

If the mechanical working is discontinued prior to complete fibrillation, the product is a network of parallel continuous filaments interconnected by means of tiny side fibrils, the fibrils being the residue of the thin web section of the striated film. The resulting net-like structure is also useful in the process of this invention. This partially fibrillated film can be expanded up to about five times its initial width without breaking the interconnecting fibrils. Obviously, the extent to which it is expanded or opened out will affect the porosity of the nonwoven fabric prepared therewith.
In order to prepare a nonwoven fabric from one of these fibrillated products, two or more of the same are cross-overlaid and bonded. Nonwoven fabrics can be prepared in this manner having a variety of porosity levels, depending upon the degree to which the partially fibrillated films are expanded to open out their net-like structure or upon the number of layers which are laid up.

The invention can be described more clearly by reference to the attached drawings, in which:

FIG. 1 is a view of a section of a striated film with the size of the striations greatly exaggerated;

FIG. 2 is a schematic illustration of one method of fibrillating a single film, for use in the invention;

FIG. 3 is a perspective view of an expanded network structure produced by the partial fibrillation of a striated film;

FIG. 4 is a schematic illustration of one method of accomplishing the laminating process and subsequent bonding of the laminated structure;

FIG. 5 depicts a typical nonwoven fabric which can be prepared by the process of the invention showing one section somewhat magnified;

FIG. 6 is a schematic illustration of another process which can be employed; and

FIG. 7 depicts another alternative method of laying up the strand.

The striated film which is fibrillated for use in this invention is illustrated in FIG. 1. It comprises a thin strip of thermoplastic material such as polypropylene, which is provided with a series of substantially uniformly spaced parallel ribs or striations 2 running longitudinally thereof and interconnected by webs 3 of reduced thickness. The film can be oriented uniaxially in the direction parallel to the striations. With uniaxial orientation, the tensile strength in the direction of the axis of orientation is greatly increased while the strength transversely is reduced so that the film can be readily split longitudinally in comparison with the webs, the striations have a relatively high resistance to splitting, so that lengthwise splitting of the film is confined to the webs and the resulting filaments correspond generally to the striations.

In FIG. 2 there is illustrated schematically a method and apparatus for carrying out the fibrillation of the striated film just described in this invention. As illustrated in FIG. 2, the striated film 1 is advanced by draw rolls 4 from feed rolls 5, these two sets of rolls defining between them a fibrillation zone. The section of striated film within this fibrillation zone is held under tension and angled over a triangle-shaped rotating bar 6, having serrated edges 7, mounted in a suitable framework and driven by suitable drive means (not shown). As the bar is rotated in the direction of arrow A, the serrated edges are successively brought into engagement with the ribbon along lines transversely thereof with each successive line of engagement spaced upstream of the ribbon from the preceding line of engagement. After engagement, the serrated edge is advanced along the ribbon and then carried out of engagement with it. With the ribbon under tension, the teeth of the serrated edges bear upon and penetrate the ribbon, separating it into filaments which are thereupon taken up on a beam (not shown).

The degree of fibrillation effected on the film is regulated or controlled by the amount of contact between the serrated edges of the beater bar and the film. Thus, to effect partial fibrillation the apparatus is operated in such a way that the serrated edges of the bar are not in contact with the film continuously. This can be accomplished, e.g., by rotating the bar at a low rate as compared to the linear rate of advancement of the film. The precise ratio of speeds is dependent upon the number of serrations per inch along the edge 7 relative to the spacing of the striations on the film and the number of such serrated edges on the bar. The degree of fibrillation can also be varied by varying the arc through which the teeth travel while in contact with the film. To effect complete fibrillation, these factors are combined in such a way as to assure substantially continuous contact between the film and the beater bar, or contact between them at substantially every point along the surface of the film.

The product of partial fibrillation shown in FIG. 3 comprises backbone filaments 8 which correspond to the thick sections 2 of the striated film and interconnecting fibrils 9 which correspond to the webs 3 adjacent to said thick sections, which webs have been split but not completely severed from their respective backbone filaments. These parallel backbone filaments are thus readily aligned in spaced apart relation, as shown in FIG. 5, by simply spreading the net-like structure.

In the method depicted in FIG. 4 for laying up layers of the fibrillated film, a plurality of substantially parallel monofilaments indicated generally at 10 are drawn from one or more supply beams 11 by means of pinch rolls 12 on a stationary mandrel 13 and form a warp. The strands are aligned in a horizontal plane as they leave the beam, but are passed through an annular former 12 which conforms them to the shape of the mandrel 13 so that the complete surface of the mandrel is covered by the filaments as shown in the area designated by the letter M. If the filaments 10 are advanced parallel to the surface of the mandrel 13, a plurality of small denier monofilaments 14 is laid on them from one or more supply beams 15, supported on a rotatable carrying means 16 and adapted to orbit the mandrel 13 at a rate correlated with the rate of advancement of the warp monofilaments 10. By the combination of the rotating motion of the carrier and the forward motion of the warp filaments, the cross filaments are laid on the warp filaments at an angle between about 20° and 89°. The now-laminar structure is drawn off the mandrel and compressed by pinch rolls 18 into a flat structure 17 composed of a center layer comprising the parallel warp-type filaments and a surface layer of parallel continuous filaments disposed at an angle to the center layer.

The pinch rolls employed to advance the fabric structure from the mandrel and compress the same can be heated to a temperature sufficient to effect the necessary degree of bonding at filament crossover points if bonding can be effected without the addition of an extraneous adhesive material. This can be the case, e.g., where the fabric comprises a mixture of thermoplastic materials, such as a mixture of polypropylene and a propylene-ethylene copolymer which softens at a lower temperature.

In a case where an extraneous adhesive is employed, it can conveniently be added following flattening of the structure by means of, e.g., spray nozzles 19, followed by drying and baking in an oven 20. Upon leaving the oven, the completed fabric 21 is collected into a mill roll 22 at a take-up station 23.

A section of the completed fabric shown in FIG. 5. The warp yarns 25 are shown substantially parallel to one another along the longitudinal axis of the fabric with cross-direction filaments 26 substantially parallel to one another but disposed at an angle, φ, to the warp filaments. The dotted lines represent the extremities of the cross-layering beams on the opposite surface of the fabric.

Useful nonwoven fabrics can be prepared according to this invention when the cross-laid filaments are disposed at an angle between about 20° and 89° to the warp filaments. Preferably the angle should be at least 45°. As the angle gets smaller, the fabric gets weaker, since the reinforcement afforded by the crossing filaments becomes less. The angle between the filaments in the warp and cross directions is determined by the ratio of the speed at which the warp filaments are advanced to that at which the cross-direction filaments are wrapped around them.

With reference to FIG. 5, the dimension R is the pattern repeat distance, i.e., the linear distance of the warp which will be cross-laid by a single cross-laying beam in
making one complete orbit around the forming mandrel, which is expressed by:

$$R = \frac{\text{speed of warp filaments}}{\text{speed of cross-laid filaments}}$$

Thus, using basic trigonometric relationships, it can be seen that:

$$\cot \theta = \frac{\text{speed of warp filaments}}{\text{speed of cross-laid filaments}} \times 1/2$$

From this relationship, $\theta$, the angle between the warp and cross filaments, can readily be determined for any combination of speeds and fabric widths.

By reference to FIG. 5, it will also be seen that, in order to cross-lay the fabric completely, so that successive wraps of cross-laying filaments are contiguous to one another, the required number of cross-laying beams is a function of the pattern repeat distance ($R$) and the width ($W$) of the cross-laying beam and can be expressed by the equation

$$\text{number of cross-laying beams} = \frac{\text{speed of warp filaments}}{\text{speed of cross-laid filaments}} \times \frac{\text{width of cross-laying beam (W)}}{W}$$

In the following table are listed examples of combinations of the above variables determined as set forth above for several operating runs for preparing fabrics according to this invention, assuming a constant fabric width of 4 feet.

<table>
<thead>
<tr>
<th>Speed of warp f.p.m.</th>
<th>Speed of cross-laid filaments r.p.m.</th>
<th>Pattern repeat distance</th>
<th>Width of cross-laying beam</th>
<th>Number of cross layer packages</th>
<th>Number of cross layer packages required</th>
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<td>1</td>
<td>8°</td>
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</tr>
</tbody>
</table>

As indicated above the fabric can be bonded by heat alone which can be applied by means of the pinch rolls 18, or they can be bonded by means of an adhesive. The adhesive can be an emulsion, dispersion, or solution of a heat activated material which will adhere to the polymer. This adhesive is activated by heat applied in the drying oven. Alternatively, small particles or fibers of a thermoplastic resin can be employed as the adhesive. These are dusted onto the fabric, then melted in the oven and they then fuse to bond the fabric upon cooling.

Bonding can also be effected by the ultrasonic technique. In this method, the unbonded structure is contacted with an ultrasonic horn which causes melting at only the point of contact of the horn. Such contact at points where filaments cross causes fusion of the filaments at that point. Other bonding techniques are known to the art and any technique suitable according to prior art practice is useful with the materials of this invention.

Chemical bonding, however, is preferred, i.e., where an adhesive material in solution or suspension is applied to the structure and cured by heating. The adhesive to be used can be selected from a wide variety of commercially available materials depending upon the identity of the thermoplastic polymer being employed in the fabric.

In the apparatus for carrying out the invention depicted in FIG. 6, the small denier monofilament 10 are drawn from supply beams 11, over a coating roll 30 where an adhesive solution, emulsion or dispersion is applied thereto. They are then drawn over forming mandrel 13 and overlaid with cross-direction strands in the manner described above. The mandrel is heated to cure the adhesive and bonding of the layers is effected while the structure is intubular form in contact with the mandrel. When the embodiment is employed, the former and the forming mandrel should be treated as with an inert, non-adherent coating, to prevent the adhesive from adhering to the filaments thereto. Upon leaving the mandrel, the tubular structure can be slit along one or both edges by means of a slitting knife 31 installed immediately ahead of pinch rolls 18. This form of the structure can then be opened out to form a fabric comprising parallel longitudinal filaments overlaid with continuous cross-direction filaments on only one of its surfaces. This fabric, of course, will have only half the thickness and half the strength of the fabric prepared according to FIG. 4, but will likewise be more flexible and more drapeable.

In the embodiment of the invention depicted in FIG. 7, the filaments are drawn off supply beam 33 by a set of pinch rolls 34 to form a warp between a pair of continuous endless wire tubes or cables 35 and 35'. The cross filaments are supplied from beam 36 adapted to rotate around the warp yarns and the belts 35 and 35' where they are held to prevent their puckering the warp. The structure thus prepared is compressed by pinch rolls 34 to retain it and the cross filaments are slit to remove them from the belts, allowing the belts to continue their revolution, while the fabric is advanced away from them.

The fabric can be bonded by the pinch rolls, if desired, or the fabric can be advanced and bonded chemically as previously described.

As has been indicated previously, a slitted film can be completely fibrillated to the point where each filament is an entity totally unconnected to any neighboring filament, or it can be only partially fibrillated to form an expandable network structure as depicted in FIG. 3. Either the partially or completely fibrillated product can be employed as the low denier monofilament strands employed in this invention. They can be handled in the same manner and they perform in the same manner except that the incompletely fibrillated product results in a slightly stiffer fabric than that prepared from completely fibrillated, completely separate filaments.

Although the invention is described in terms of preparing the novel fabrics from filaments resulting from fibrillation of slitted films, it should be clear that this is not a limitation on the same. Individual small denier monofilament strands from any source can be employed so long as they can be collected on a beam and drawn off in substantially parallel fashion onto the forming mandrel. The emphasis on fibrillated slitted films is intended as a recognition that the fibrillation technique represents the most practical method yet devised for preparing the required starting material.

Nonwoven fabrics according to the invention can be prepared from filaments of any of the conventional thermoplastic fiber-forming polymers. Exemplary of such materials are polypropylene, nylon, polymers such as poly(ethylene terephthalate) and acrylics such as polyacrylonitrile and the like. Moreover, blends of these various polymeric filaments can also be employed when specific combinations of properties are desired. It is also feasible to employ bi-component filaments having components of differing properties as, e.g., differences in melting points to facilitate bonding. The composite or bi-component technique also can be advantageous in imparting latent crimp to the fibers. When such fibers are heated and their bulk increase, they exhibit substantially higher covering power. It is also possible, if desired, to employ foamed filaments.

Nonwoven fabrics prepared by the process of this invention can be employed in any of the applications where nonwovens are conventionally employed. One such appli-
cation is in the preparation of reinforced paper where a web of pulp is laid on either side of the nonwoven fabric and calendered to the proper thickness. Such reinforced paper is attractive in, e.g., preparation of certain types of disposable garments, in that it has excellent drape properties due to the long, fine denier filaments in the reinforcing fabric. Other applications for the nonwovens prepared by the process of the invention include bagging, filter fabrics, and carpet backing.

The specific mechanical embodiments of the invention disclosed herein relating to the fibration of the striated film and to the overlying of the lamina are intended as illustrations only. The invention is not limited to these methods.

What I claim and desire to protect by Letters Patent is:

1. A method of making a nonwoven fabric which comprises:
   continuously advancing in a direction intended as the warp direction of the fabric a first open network of spaced apart substantially parallel continuous monofilaments, adjacent ones of which are interconnected by a plurality of fibrils;
   continuously overlying a second open network of spaced apart substantially parallel continuous monofilaments adjacent ones of which are interconnected by a plurality of fibrils, across at least one surface of said first network at an angle of about 20° to 89° to the warp direction of said first network; and
   bonding the monofilaments of one network to the monofilaments of the other network at their cross-over points to form a multi-layer nonwoven fabric, each layer having a uniform thickness substantially equal to the thickness of the individual monofilaments of the layer.

2. A method according to claim 1 wherein the monofilaments of the first network are disposed in a flat configuration and the monofilaments of the second network are overlaid on both surfaces thereof.

3. A method according to claim 2 wherein the monofilaments of the first network are fusion bonded to the monofilaments of the second network.

4. A method according to claim 2 wherein bonding is effected by means of a heat activated adhesive.

5. A method according to claim 1 wherein the monofilaments of one network are fusion bonded to the monofilaments of the other network.

6. A method according to claim 1 wherein bonding is effected by means of a heat activated adhesive.

7. A method of making a nonwoven fabric which comprises:
   providing a first open network of spaced apart substantially parallel continuous monofilaments adjacent ones of which are interconnected by a plurality of fibrils;
   forming said first network into a generally tubular or cylindrical configuration and advancing said formed network in a direction intended as the warp direction of the fabric;
   continuously overfaying the periphery of said tubular configuration with a second open network of spaced apart substantially parallel continuous monofilaments adjacent ones of which are interconnected by a plurality of fibrils at an angle of about 20° to 89° to the warp direction of said first network;
   flattening said tubular configuration; and
   bonding the monofilaments of one network to the monofilaments of the other network at their cross-over points to form a multi-layer nonwoven fabric, each layer having a uniform thickness substantially equal to the thickness of the individual monofilaments of the layer.

8. A method according to claim 7 wherein the monofilaments of one network are fusion bonded to the monofilaments of the other network.

9. A method according to claim 7 wherein bonding is effected by means of a heat activated adhesive.

10. A method of making a nonwoven fabric which comprises:
   providing a first open network of spaced apart substantially parallel continuous monofilaments adjacent ones of which are interconnected by a plurality of fibrils;
   continuously forming and advancing said first network in the warp direction in a generally tubular or cylindrical configuration;
   providing a second open network of spaced apart substantially parallel continuous monofilaments adjacent ones of which are interconnected by a plurality of fibrils;
   continuously overfaying said second network about the periphery of said tubular configuration at an angle of about 20° to 89° to the monofilaments of said first network;
   bonding the monofilaments of one network to the monofilaments of the other network at their cross-over points to form a multi-layer nonwoven fabric, each layer having a uniform thickness substantially equal to the thickness of the individual monofilaments of the layer;
   and
   splitting the fabric along at least one edge thereof and opening the fabric out to form a fabric having a single layer of warp direction monofilaments and a single layer of cross-direction monofilaments.

11. A method according to claim 10 wherein the monofilaments of one network are fusion bonded to the monofilaments of the other network.

12. A method according to claim 10 wherein bonding is effected by means of a heat activated adhesive.

13. A nonwoven fabric comprising a first open network having a plurality of substantially parallel continuous synthetic thermoplastic polymer monofilaments in a single layer in spaced apart side-by-side relationship with adjacent monofilaments being interconnected by a plurality of fibrils, and a second open network having a plurality of substantially parallel continuous synthetic thermoplastic polymer monofilaments in a single layer in spaced apart side-by-side relationship with adjacent monofilaments being interconnected by a plurality of fibrils, said second network being cross-laid on at least one surface of said first network so that the plurality of monofilaments of said second network are disposed at an angle of about 20° to 89° to the plurality of monofilaments of said first network, said first plurality of monofilaments being bonded to said second plurality of monofilaments at their cross-over points to form a multi-layer nonwoven fabric, each layer of which has a uniform thickness substantially equal to the thickness of a single monofilament in said layer.

14. The nonwoven fabric of claim 13 wherein the monofilaments are of a propylene polymer.

15. The nonwoven fabric of claim 13 wherein said plurality of monofilaments of said first and second networks are of a bicomponent polymer, one component of which has a lower melting point than the other component.

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