

April 5, 1955

DE WITT R. PETTERSON ET AL

2,705,687

NONWOVEN FABRIC AND METHOD OF PRODUCING SAME

Filed April 7, 1952

3 Sheets-Sheet 1

Fig. 1.

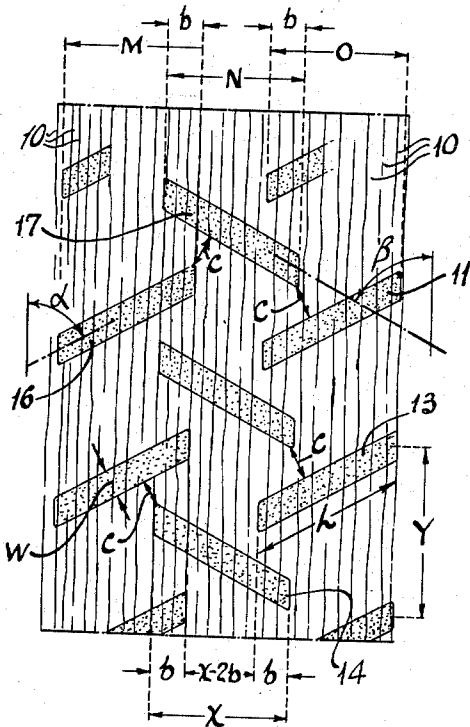


Fig. 2.

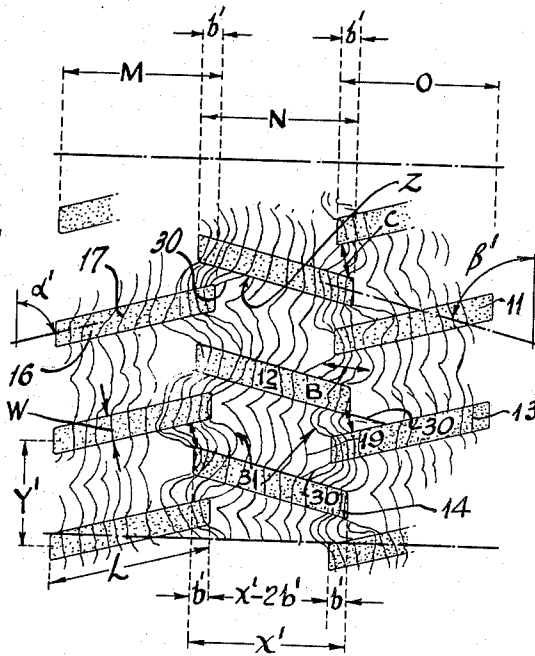


Fig. 3.

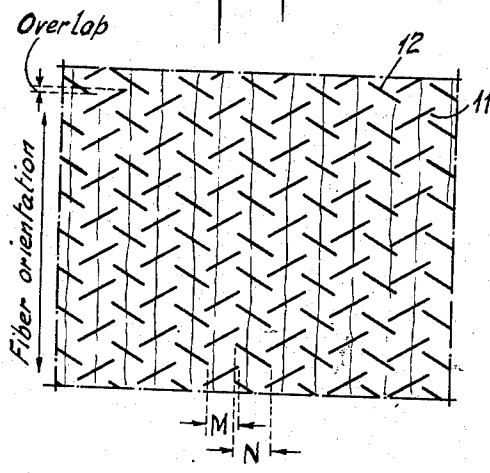
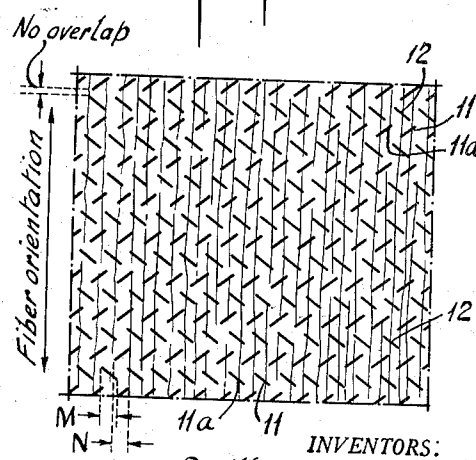


Fig. 4.



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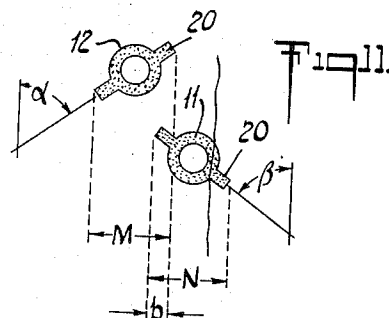
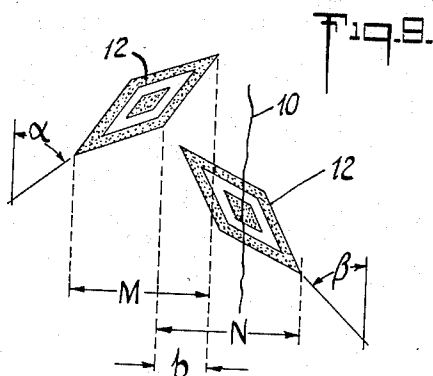
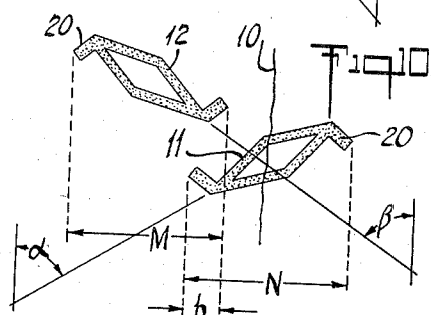
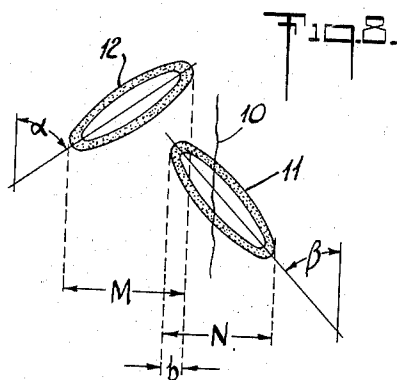
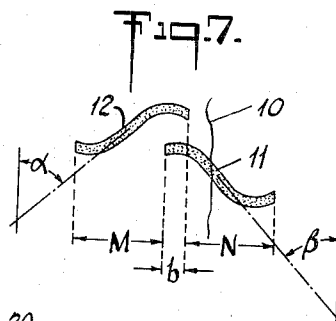
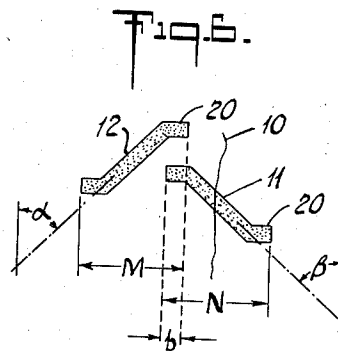
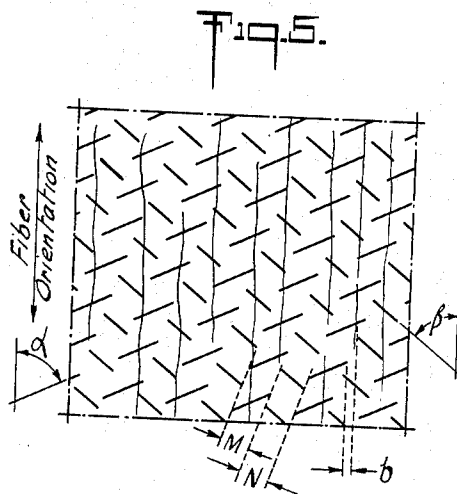
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NONWOVEN FABRIC AND METHOD OF PRODUCING SAME

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3 Sheets-Sheet 2



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NONWOVEN FABRIC AND METHOD OF PRODUCING SAME

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3 Sheets-Sheet 3

Fig. 12.

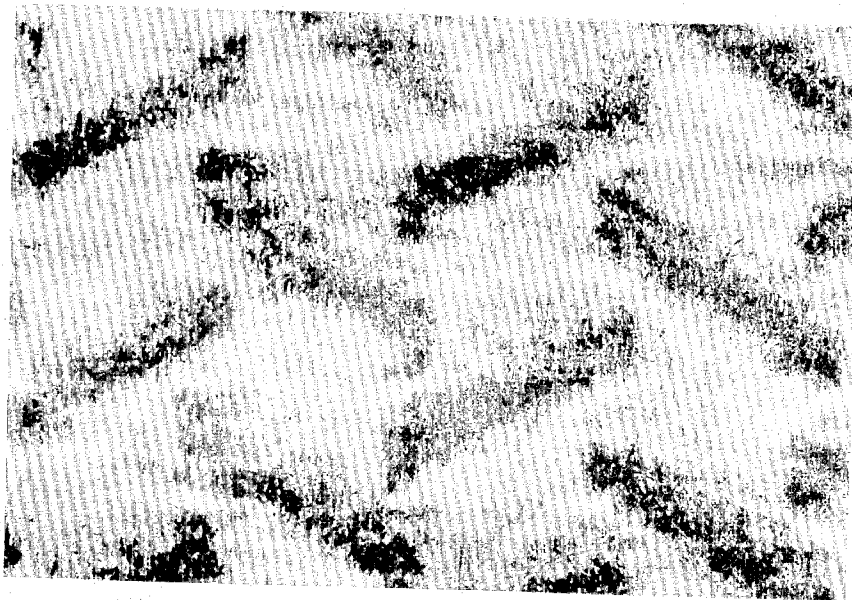


Fig. 13.



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1

2,705,687

NONWOVEN FABRIC AND METHOD OF PRODUCING SAME

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Application April 7, 1952, Serial No. 280,962

18 Claims. (Cl. 117-44)

The present invention relates to textile fabrics and their manufacture. More particularly it is concerned with so-called "nonwoven" fabrics, i. e., fabrics produced from textile fibers without the use of conventional weaving or knitting operations. Although not necessarily limited thereto, the invention is of primary importance in connection with "oriented" nonwoven fabrics composed of textile fibers, the major proportion of which are substantially "parallelized" or oriented predominantly in one direction.

Nonwoven fabrics of various types have become increasingly important in the textile field during the past decade, primarily because of their low cost of manufacture compared to fabrics formed by weaving or knitting spun yarns. Nonwoven fabrics are particularly suitable for applications where launderability is not a prerequisite, or low cost is an important consideration, especially in the case of finished products that are used once and then discarded, as for example in the manufacture of sanitary napkins; surgical dressings; casket liners; or disposable table napkins, hand towels, diapers, drapery fabrics and the like.

The conventional base material for nonwoven fabrics is a web comprising any of the common textile-length fibers, or mixtures thereof, the fibers varying from approximately one-half inch to two and one-half inches in average staple length. These fibers are customarily processed through any suitable machinery (e. g., the conventional cotton card) to form a web or sheet of loosely associated fibers, weighing anywhere from about 100 to about 4000 grains per square yard or even higher. This essentially two-dimensional web or sheet of fibers is produced continuously with the fibers substantially parallelized or oriented in the "machine direction," i. e., the direction in which the product moves continuously from the sheet-forming machine. In such a web, the degree of orientation, or ratio of oriented to non-oriented fibers varies roughly from about 70% to about 90%; i. e., from 10% to 30% of the fibers are non-oriented while from about 70% to 90% of the fibers are substantially parallelized in the machine direction.

The resulting web or sheet is subjected to one of several types of bonding operations to anchor or bond the individual fibers together. One method is to impregnate the web over its entire width with various well-known bonding agents such as natural or synthetic resins. Such over-all impregnation produces a product of good longitudinal and cross strength. However, the product tends to be stiff and boardlike, possessing more of the properties of paper or board than of a woven textile fabric: over-all impregnated webs are therefore generally unsatisfactory as textile fabrics.

Another well-known bonding method is to print nonwoven webs with continuous straight or wavy lines of binder extending transversely across the web. The resulting nonwoven fabric, as exemplified by the product disclosed in the Joshua Goldman Patent 2,039,312 and by that heretofore sold by the present assignee under the trade-mark "Masslinn," is far more satisfactory as a textile fabric than impregnated webs in that the softness, drape, and hand of the resulting fabric more nearly approach those of a woven textile fabric. However, the Joshua Goldman type of product in the cross direction is characterized by low elongation properties, relatively low degree of elasticity and a low energy absorption to break. For these reasons, the product upon stressing in a direction transverse to the direction of fiber orientation, tends

2

to rip, tear or develop irregular holes due to rapid rupture of the continuous binder lines.

More recently discontinuous or "spot bonding" has been proposed. This type of bonding involves the use of relatively tightly spaced, circular or hexagonal solid dots or spots arranged in a staggered pattern, as exemplified by the product disclosed in the Esther Goldman Patent 2,545,952. Such "spot-bonded" products are relatively flexible when the fabric is bent upon itself. However, flexibility has been attained at the sacrifice of other desirable properties. Thus the Esther Goldman type of product, although excellent in respect to cross tensile strength, has a low degree of elasticity, moderately low energy absorption to break, low elongation in the cross direction, and is especially paper-like or board-like, lacking the softness, drape and loft characteristic of conventional textile fabrics.

From the foregoing analysis it will be seen that none of the nonwoven fabrics of the prior art has been entirely satisfactory, particularly in the cross direction in respect to degree of elasticity, initial modulus of elasticity, energy absorption to break, elongation and tensile strength, in combination with the desirable textile properties of softness, hand and drape.

Generally speaking, one of the objects of the present invention is to provide a nonwoven fabric that is not subject to the foregoing and other disadvantages. Expressed affirmatively, the general object of the invention is the provision of a nonwoven fabric characterized by a number of desirable properties never heretofore attainable in combination, so far as we are aware.

More specifically, our object is to provide a nonwoven fabric characterized by one or more of the following properties:

1. High degree of elasticity (i. e., instantaneous recovery or "snap-back") when subject to stress in the crosswise direction;
2. High secondary creep (i. e., latent recovery, with time) after the fabric has been stressed crosswise and then permitted to relax;
3. High initial modulus of elasticity in the cross direction;
4. High energy absorption to break in the cross direction;
5. Good cross strength;
6. High cross elongation;
7. Excellent textile-like properties such as softness or hand, flexibility or drape, and the three-dimensional appearance or loft characteristic of woven fabrics; and
8. Capacity to develop a more pronounced loft upon release from temporary deformation in a direction perpendicular to fiber orientation, with a further improvement in the above mentioned textile-like properties, especially softness and loft.

Still another object is the provision of a novel binder pattern or design that is capable of imparting the foregoing properties, in a controllable degree and relationship, to an unbonded nonwoven oriented textile web.

An additional object is to provide a simple, commercially feasible and economical method of manufacturing an improved nonwoven fabric having the properties mentioned above.

A further object is to utilize the normally oriented fibers in a card web to impart the above properties to the finished nonwoven fabric.

Other objects and advantages of the invention will become apparent as the description progresses.

We have found that the foregoing objects may be attained in accordance with the present invention, one aspect of which involves a web of fibers bonded together by means of a novel binder pattern that may be characterized broadly as an inherently elastic, articulated, multisegmental binder pattern. An oriented web of fibers bonded together by such a binder system possesses properties suggestive of those of a skeletal system. In the pattern of the present invention, the individual segments, elements, or component parts comprising the "skeletal system" are bonded areas that are separated from each other by otherwise unbonded fibers but that are nevertheless "hinged," "jointed," or "articulated" with respect to each other by unbonded lengths of fibers. In this sys-

tem the individual bonded segments or elements may be likened to the bony portion of the skeleton, while the fibers hingedly interconnecting the segments act in effect like the crucial tendons and cartilaginous elements in a skeletal joint.

Regardless of the aptness of the analogy suggested immediately above, the individual binder areas and the fibers comprising the web are so interrelated as to interact in a novel elastic or spring-like manner when the web is stressed in a crosswise direction. By virtue of this elastic mode of interaction, an extraordinary combination of properties is attainable in the bonded web, including, among other characteristics, high degree of elasticity, high energy absorption to break, high strength and high elongation, all in the cross direction, without sacrifice of those properties such as hand, drape, and loft that are important to the use of the resultant nonwoven fabric as a textile material.

In the preferred embodiment of the present invention, a web of fibers, oriented or parallelized to a substantial degree, is formed into a nonwoven fabric by bonding with an articulated, multisegmental pattern of binder, the individual segments of which pattern comprise elongated, discrete areas of binder infused locally into the body of the web and separated from each other by substantially unbonded lengths of fibers. The major axes of the elongated binder areas are disposed obliquely (i. e., neither perpendicularly nor parallel) with respect to the direction of fiber orientation, and with the binder areas adjacent each other preferably angularly disposed with respect to each other. Each elongated area is hingedly interconnected or articulated with its neighboring areas by substantially unbonded lengths of oriented fiber.

Desirably the elongated and obliquely inclined binder areas are of uniform (but not necessarily identical) configuration and dimensions, and they are uniformly arranged in a staggered pattern extending across the entire width of the web in a direction transverse to the machine direction, or direction of "fiber lay." The elongated areas are disposed with their major axes inclined with respect to the fiber lay, and arranged in a series of overlapping columns that are parallel to each other and preferably (but not necessarily) parallel to the direction of fiber orientation. In any event, the over-all binder distribution pattern is such that in the area or zone of overlap every line parallel to the direction of fiber orientation passes through at least three diagonally inclined, hingedly interconnected, elongated binder areas within a distance along said line equal to the average length of the fibers composing the web. The "parallel" fibers of average length or greater in the overlap area are therefore, in the main, bonded by at least three inclined, elongated areas of binder, two of which lie predominantly in one column, while the third area, positioned between the first two areas, lies predominantly in an overlapping, parallel column.

In order more clearly to disclose the nature of the present invention and the manner in which it may be carried into practice, it is desirable to set forth certain considerations which we believe will aid in its comprehension. It should be clearly understood, however, that this is done solely in aid of its understanding; the present invention is in no way dependent upon the correctness of any theoretical considerations hereinafter presented nor, indeed, upon the aptness or inaptness of any analogies that may herein be suggested for the purpose of relating the invention to more familiar concepts.

In the following discussion reference will be made to the several figures of the drawing, wherein:

Fig. 1 is a plan view on an enlarged scale diagrammatically showing a relaxed portion of a nonwoven fabric having a binder pattern in accordance with a preferred embodiment of the present invention;

Fig. 2 is a similar view, also on an enlarged scale, diagrammatically showing a portion of the fabric of Fig. 1 when stretched or extended in a direction transverse to the direction of fiber orientation;

Fig. 3 is a plan view, approximately full scale, of a portion of fabric having a binder pattern in accordance with a preferred embodiment of the invention, the pattern consisting of a "cross-hatch" design.

Fig. 4 is a similar view, approximately full scale, showing the geometry of a similar binder design having shorter segments;

Fig. 5 is a plan view, approximately full scale, showing

a portion of a fabric provided with modification of the binder design of Figs. 3 or 4, the parallel columns of binder areas being inclined slightly with respect to the direction of fiber orientation;

Fig. 6 is a plan view on an enlarged scale of a portion of a fabric having a modified form of binder pattern, involving straight lines with obliquely extending "tails";

Fig. 7 is a similar view on an enlarged scale, showing another modification of the individual binder areas, comprising S-shaped curved lines;

Fig. 8 is a similar view on an enlarged scale showing still another modification of the binder areas, and involving hollow oval-shape binder areas;

Fig. 9 is a similar view, on an enlarged scale, showing a further geometrical modification of the binder areas, and involving solid diamond-shaped areas disposed within hollow diamond-shaped areas;

Fig. 10 is a similar view on an enlarged scale of a still further geometrical variation wherein the individual binder areas consist of hollow diamond-shaped areas provided with obliquely extending tails;

Fig. 11 is a similar view on an enlarged scale showing another geometrical variation wherein the binder areas comprise hollow circles provided with opposed radial extensions or tails;

Fig. 12 is a photomicrograph showing the surface of a web bonded in accordance with Fig. 2 of the present invention, the fabric being in the relaxed state; and

Fig. 13 is a photomicrograph of the fabric of Fig. 12 when subjected uniformly to a state of tension in a direction across the direction of fiber orientation.

The present invention utilizes separate, discrete, elongated areas of resin or binder so disposed and related to each other and to the fibers as to impart to the web, in the cross direction, a high degree of elasticity, high initial modulus of elasticity and high energy absorption to break, while permitting control of these properties relatively independently of each other in the design of fabrics intended for specific end uses. So far as we are aware this has not been possible with any previous binder design.

In accordance with the present invention the optimum balance of desirable qualities for a nonwoven textile fabric is attainable by using elongated areas of binder so positioned with respect to each other as to be hingedly joined at their ends to adjacent binder areas by a bundle of parallel, substantially unbonded lengths of fibers. For reasons hereafter explained, in order to attain a high degree of elasticity, a substantial proportion (preferably all) of the elongated binder areas are inclined obliquely with respect to the direction of fiber orientation.

Referring now to the drawings, particularly Figs. 1 and 2, these figures diagrammatically illustrate the underlying principles of the present invention. Fig. 1 shows a greatly enlarged section of fabric in a relaxed condition while Fig. 2 shows a section of the same fabric when placed under tension in the cross direction. As shown in Fig. 1, the fabric comprises substantially parallelized fibers 10 bonded together by uniform staggered pattern of elongated and inclined binder areas 11, 12, 13, 14, 15, 16 and 17, infused locally into the body of the web and separated from each other by substantially unbonded lengths of fibers. The elongated areas of length L and width W desirably are uniformly arranged in overlapping columns M , N and O , having a width X , the width of overlap being designated by b . The elongated areas in one column (e. g., M) are inclined with respect to the direction of fiber orientation by an angle α while those in an overlapping column (e. g., N) are inclined at an angle β preferably identical with the angle α but in the opposite sense or direction. The columnar (i. e., vertical) distance between elongated binder areas along the axes of the parallelized fibers is indicated by Y . The "shortest clear distance" between adjacent areas is designated by C .

When the fabric of Fig. 1 is stressed in the crosswise direction, each binder area tends to move to relieve the strain, assuming the relationship illustrated in Fig. 2. The angles of inclination α' and β' of each elongated area are greater than before as well as the width (X') of the overlapping columns. On the other hand, the columnar distance (Y') between elongated areas in a given column, the extent of overlap (b') between overlapping columns, and the shortest clear distance (c')

5

between neighboring elongated areas are all less than before.

Considering the centrally located binder area 12 in Fig. 2, it will be apparent from inspection that this area is subject to an unequal distribution of forces about its periphery. In other words, the forces acting upon this area (and every adjacent area) are now unbalanced. The lengths of fibers 19 between the central portions of the elongated areas 12 and 14 are buckled, "puckered" or bent out of the original plane of the sheet and because of their tendency to straighten out, tend to push the connected areas 12 and 14 apart.

The originally relaxed "hinge fibers" in the band *b*, connecting adjacent ends of neighboring areas are now disposed in unequal states of tension or compression, as diagrammatically shown in Fig. 2 by the taut fibers 30 and the bent fibers 31. As a result of an asymmetrical distribution of these tension and compression forces, the binder area 12 is subject to a torque along its major axis. This torque, coupled with the various other forces acting asymmetrically around the periphery of the binder area 12, tends to resist further deformation and (when the stress is relieved) to restore the area 12 and adjacent areas to their original positional relationship as shown in Fig. 1.

Thus, in accordance with our invention, by disposing elongated, discrete but articulated areas in such a manner as to produce an asymmetrical distribution of forces around their peripheries when the fabric is stressed, a high degree of elasticity is "designed into" a web that originally was essentially devoid of either strength or elasticity in the cross direction. Furthermore, by proper adjustment of the dimensions of the elongated areas, their "inter-island" distances and their angular and spacial relationships, it is possible, within wide limits, for those skilled in the art to "engineer into" a finished fabric the optimum combination of properties desired for any specific end-use of the material.

The foregoing will be more readily apparent from the following analysis of the factors effecting some of the more important properties of the fabric.

1. Factor affecting strength

Referring again to Figs. 1 and 2, the band of fiber lengths in the overlap area *b* are of a strong, flexible nature, and are held together by the centers of the elongated resin or binder areas. Since the fiber band strength can be increased by increasing the extent of overlap *b*, the strength of the material will depend in part upon the degree of overlap (*b*). Ultimately, however, cross strength will depend upon the strength available in the center of each of the elongated areas for holding these bands together under stress, assuming proper overlap.

Within limits, any factor tending to increase overlap will tend to increase cross strength. The degree of overlap (*b*, Figs. 1 and 2) should not be less than about 0.02 of an inch, and preferably should lie between about 0.04 and about 0.06 of an inch. Overlap may, of course, be increased by increasing the length of the elongated areas without changing their center-to-center distances, for example, by putting inclined extensions or "tails" on the area, as shown in Figs. 6, 7, 10 and 11, the extensions being inclined, if desired, transversely to the fiber direction to attain maximum overlap for the amount of binder used. Another expedient for increasing overlap is to interpose between neighboring inclined segments a horizontally disposed, staggered or "overlap segment" hingedly connected to the inclined segments. Further increase in overlap, beyond approximately 0.04 inch does not appear materially to increase cross strength: for, generally speaking with this amount of overlap, the region of the overlap (like some of the joints in a skeletal system) constitutes the strongest part of the fabric when stressed in the cross direction.

To increase the inherent strength in the binder area, the width (*W*) of the elongated area (i. e., its minor axis) may be increased adjacent the overlap zone in the central portion of the area so that *W* is greater at the center of the area than at its ends. A number of modifications in geometry of the individual elongated areas to increase the minor axis at the central portion of the elongated area will readily suggest themselves. Some of these modifications are shown in Fig. 8 (hollow oval-shaped areas), Fig. 9 (solid diamond in hollow diamond-shaped areas), Fig. 10 (hollow diamond-shaped areas

6

with oblique tails), and Fig. 11 (hollow circles with radially extending tails). Innumerable other variations will be readily apparent to those skilled in the art.

2. Factors affecting elongation

The elongation of the fabric under stress will be effected by the "inter-island" distances *X*, *Y* and *C*, and by the angles α and β at which the elongated areas are inclined to the fiber direction. For a given strength, it is possible to increase or decrease the elongation properties by changing these "inter-island" distances and the angles of inclination.

3. Factors affecting total energy absorption to break

This property is indicative of the amount of work necessary to rupture the material and is approximately equal to one-half the breaking load times the elongation. In general, previous fabrics have been characterized by either high strength and low elongation, or low strength and high elongation. Both of these give relatively small and approximately equal work loads or energy absorption to break. The present invention permits substantially increasing the work load capacity by achieving a proper balance of cross strength and elongation. This property is controlled by the factors effecting the two properties discussed in the previous sections.

4. Factors affecting degree of elasticity

When a section of the fabric in accordance with this invention is stretched in the crosswise direction, there is a tendency for the inter-resin distance *Y* to decrease as the hinged band of "cartilaginous fibers" of width *b* is deformed (Fig. 2). The decrease in columnar distance *Y* causes a pucker or distortion of the fibers lying between the lengths $X-2b$ of two adjacent resin areas in a column. Upon removal of stress, these distorted or puckered fibers 19 lying primarily above and below the plane of the sheet proper have a tendency to push the resin areas back to their original position. The magnitude of this force is dependent primarily on the distance $X-2b$ since this controls the number of fibers so distorted. In the band of fibers now displaced to a zigzag position, the inclination of the resin areas causes an unequal distribution of stress, tending to decrease the angle of inclination and thereby cause unequal stress distribution on one side or the other of the "fiber hinge" or "crucial tendon" *b*. This unequal distribution of stress in the fiber hinge causes a torque to be set up on the ends of the elongated resin area, tending to turn the extremities of this area out of the plane of the web. This area of fibers bound between neighboring resin areas might be described as a spring where the distance *C* indicates the length of the spring, the length *b* indicates the width of the spring and the angles of inclination α and β are proportional to the torque or unsymmetrical force distribution set up within the spring. Accordingly, elasticity is affected, in part by the length *L* of the elongated area, the distance $(X-2b)$, the overlap *b*, the clear distance *c*, and the angles of inclination α and β of the resin or binder area. For optimal elasticity the major axis *L* of the elongated areas preferably should be at least six or seven times the minor axis *W*, in order to increase $(X-2b)$; in addition, the angles α and β preferably should lie between about 30° and 60°, e. g., about 45°.

5. Textile properties

In general, flexibility, drape, softness, and three-dimensional effect, or loft, are enhanced by increasing the inter-resin area distances *X*, *Y* and *C* or by decreasing the area dimensions *L* and *W*, i. e., by decreasing the proportion of lateral surface covered by the binder. The latter is, of course, a basic factor in softness as well as in strength, elongation, energy absorption to break and elasticity, among others. Generally speaking, desirable textile properties are attained to an adequate degree only if not substantially more than about 35% of the lateral surface of the web is bonded. With the present binder pattern the binder may be, and preferably is, used sparingly, with the bonded areas covering about 10 to 25% of the total lateral surface of the web or sheet.

Referring now to Figs. 3, 4, and 5, all these are plan views, roughly full scale, showing a portion of the simple "cross-hatch" type of binder pattern forming a preferred

embodiment of the invention and discussed above in connection with Figs. 1 and 2.

In Fig. 3 the inclined lines "overlap" in the direction of fiber orientation and also in the horizontal direction. In Fig. 4, however, there are "clear channels" between horizontal rows of the inclined lines: i. e., there is no "overlap" in the horizontal plane. The inclined lines of Fig. 4 are shorter and more tightly packed than those of Fig. 3.

In Fig. 5, the columns (e. g., M and N) although parallel, do not substantially overlap as in Figs. 1 to 4. However, effective overlap (*b*) in the direction of fiber orientation is provided by inclining the columns M and N obliquely across the fiber direction.

In Fig. 6, the inclined elongated binder areas comprise bars 11 and 12, each of which has terminal extensions or "tails" 20 extending perpendicularly with respect to fiberlay and thereby serving to increase the overlap *b*.

In Fig. 7, the inclined areas comprise integration signs or S-shaped curves 11 and 12, the ends of which are inclined toward the horizontal, thereby increasing the effective overlap *b*.

Figs. 8 to 11 illustrate various expedients for increasing the width of the central section of the inclined elongated areas. In Fig. 8 the areas are oval-shaped, with the major axes inclined at the angles α and β . In Fig. 9, the areas are diamond-shaped, with their major axes inclined at the angles α and β .

In Fig. 10 the strength across the center of the binder area is increased and the amount of binder is reduced by

In carrying the present invention into practice, any of the conventional web-forming, printing and drying operations, well-known in the nonwoven fabric art, and any of the conventional binder media of the prior art may be used. Typical procedures and binder media applicable in the practice of the present invention include those disclosed in Joshua Goldman Patent 2,039,312, or in the Joseph Goldman Patent 2,407,548, or in the Esther Goldman Patent 2,545,952. Such operations and media, being well known and conventional, need not be described herein, since reference may readily be made to the prior art, including the patents mentioned.

Assuming the use of an engraved printing roll of the intaglio type (as described, for example, in the Esther Goldman patent), the surface of the print or applicator roll is engraved with a pattern such that, when the binder carried in the binder-receiving recesses is transferred to the base fabric, it imprints thereon a binder pattern corresponding to any one of those shown in the several figures of the drawings and having approximately the dimensions given in Table I.

Typical properties of finished webs made in accordance with preferred embodiment of the invention are summarized in Table I. The binder employed comprised an aqueous emulsion of polyvinyl acetate. The base web consisted of a card web of one and one-half denier rayon fibers of one and one-half inch average staple length, the web having an average grain weight per square yard before printing as shown in the table. The average grain weight per square yard after printing is also shown in Table I.

TABLE I

Code Number		Pattern Geometry								Web Weight in Grains		Properties							
		Basic Type	Dimensions								Before Printing (grains/yd. ²)	After Printing (grains/yd. ²)	Cross-Strength ¹ (#/in.)	Elongation to Break ² (%)	Energy Absorption to Break ³ (in. #)	Initial Modulus ⁴ (#/in.)	Degree of Elasticity at 50% Energy Absorption To Break ⁵ (%)	Permanent Deformation ⁶ (%)	Lateral Coverage ⁷ (%)
			L In.	W In.	X In.	b In.	Y In.	C In.	α or β Degrees	X-2B In.									
C-1382	Fig. 1		0.40	0.06	0.32	0.04	0.32	0.06	60	0.24	660	885	1.65	43	0.21	6.6	36	4	30
I-B-3A	Fig. 1		0.46	0.08	0.38	0.08	0.35	0.03	60	0.22	660	970	1.95	22	0.21	3.1	59	1	35
#5	Fig. 1		0.22	0.04	0.20	0.04	0.15	0.03	60	0.12	660	790	2.1	20	0.21	49.5	50	0	23
I-G-1	Fig. 1		0.34	0.05	0.30	0.05	0.30	0.06	60	0.20	660	940	2.2	24	0.27	35.0	47	1	22
I-G-4	Fig. 3		0.18	0.04	0.16	0.05	0.30	0.07	60	0.06	660	1,010	2.86	59	0.85	40.0	12	2	15
I-H	Fig. 5		22-34	0.04	0.24	0.06	0.30	0.08	60	0.20	660	870	1.4	38	0.27	18.7	41	4	33
I-F	Fig. 10		0.44	0.06-12	0.44	0.12	0.35	0.08	60	0.12	660	780	1.57	35	0.28	5.6	23	1	21
I-E	Fig. 7		0.40	0.04	0.34	0.12	0.28	0.08	60	0.12	660	950	2.75	17	0.23	55.5	64	1	31
II-E	Fig. 11		0.16	0.04-10	0.14	0.05	0.40	0.08	60	0.04	660	960	2.31	88	1.02	19.2	11	33	

¹ ASTM D-39-49.

² ASTM D-39-49.

³ Tested under conditions above. Terms defined by H. D. Smith in ASTM Proc., 44 p. 543-592 (1944).

⁴ Same as 3.

⁵ Same as 3.

⁶ Permanent Deformation is the ratio of unrecoverable extension to gauge length after 1 hour relaxation, following stressing to 50% Energy Absorption to Break, or to 80% of Cross-Strength to Break, or to 80% of Elongation to Break.

⁷ Lateral coverage. Percent of fabric surface occupied by resin.

employing hollow diamonds. In addition, "overlap" is increased by the lateral extensions 20. In Fig. 11 increased strength at the center of the area is provided by the annular shaped central body portion 11. Opposed radially extending "tails" 20 give an otherwise completely symmetrical figure a major and a minor axis, the former being obliquely inclined by the angles α and β . The "tails" 20 serve to increase the overlap (*b*) while the asymmetric positions of the areas relative to the direction of fiber orientation give the fabric elasticity.

Figs. 12 and 13 are photomicrographs (less than 2×1 power) showing a fabric bonded as in Fig. 3. Fig. 12 shows the fabric in the relaxed condition while Fig. 13 shows the same fragment of fabric in a state of tension across the fiber direction. The development of the tiny "pillows" of puckered fibers between the binder areas is visible in this figure.

EXAMPLES

In order still more clearly to disclose the manner in which the invention may be carried into practice, several specific embodiments will hereinafter be described in detail. It should be understood, however, that this is done purely by way of example and not for the purpose of delineating the breadth of the invention or limiting the ambit of the appended claims.

Having now described the invention in specific detail and exemplified the preferred manner in which it may be carried into practice, it will readily be apparent to those skilled in the art that innumerable variations, applications, modifications and extensions of the basic principles involved may be made without departing from its spirit or scope. Thus the fabric of the instant invention may be laminated with other fabrics, with paper, or with other materials, or employed in a host of ways that will be readily apparent to the skilled artisan. We, therefore, intend to be limited only in accordance with the appended patent claims.

The term "textile fibers" as used herein includes the conventional fibers that are spun into yarn and woven into cloth. Generally speaking, the term includes fibers having an average length of one-half inch or more.

We claim:

1. A web of fibers predominantly oriented in one direction, bonded together by an articulated multisegmental binder pattern, the individual segments of which are separated from, but hingedly connected to, each other by substantially unbonded lengths of fibers, a substantial proportion of said segments being inclined obliquely with respect to the direction of fiber orientation.

2. A web of oriented fibers bonded together by a

staggered pattern of elongated binder areas infused locally into the body of the web and uniformly distributed over the entire surface of the web, each elongated area being hingedly connected to its neighboring areas by unbonded lengths of oriented fibers, a substantial number of said elongated areas being positioned asymmetrically with respect to the direction of fiber orientation so that when the bonded web is stressed in the cross direction there is set up about said asymmetrically positioned areas an asymmetric distribution of forces tending to restore the web to its original state before the stress was applied.

3. A web of carded fibers substantially all of whose fibers lying in parallelism are bonded together by a binder infused into the body of the web in an articulated multisegmental binder pattern occupying a minor portion of the surface area of said web, each of said segments being elongated and each of said segments extending obliquely across the direction of fiber alignment.

4. A web of fibers oriented predominantly in one direction, the fibers lying in parallelism being bonded together by a multiplicity of elongated areas of binder, uniformly separated from, but hingedly connected to, each other by substantially unbonded areas of fiber, said binder areas being arranged uniformly in overlapping columns that are parallel to each other and to the direction of fiber orientation, the major axis of said elongated areas being inclined with respect to the direction of fiber orientation.

5. A web according to claim 4 wherein adjacent columns overlap to the extent of at least 0.02 of an inch.

6. A web according to claim 4 wherein the elongated areas in one column are inclined in the opposite sense or direction relative to the angle of inclination of the elongated areas in an overlapping column.

7. A web according to claim 4 wherein the major axis of said elongated areas is at least twice the minor axis of said elongated areas.

8. A web of fibers oriented predominantly in one direction, the fibers lying in parallelism being bonded together by a uniform binder pattern comprising a multiplicity of elongated areas of binder, uniformly separated from each other by substantially unbonded areas of fiber and arranged uniformly in overlapping columns that are parallel to each other and to the direction of fiber orientation, the major axis of said elongated areas being inclined obliquely with respect to the direction of fiber orientation, said binder pattern being such that every line in the zones of overlapping columns parallel to the direction of fiber orientation passes through at least three binder areas within a distance along said line equal to the average length of the fibers composing the web.

9. A web of fibers oriented predominantly in one direction, the fibers lying in parallelism being bonded together by a symmetrical pattern comprising a multiplicity of uniform, elongated, discrete areas of binder, uniformly separated from each other by a substantially unbonded area of fiber and arranged in parallel, uniformly overlapping columns, the major axis of said elongated areas being inclined obliquely with respect to the direction of fiber orientation, said symmetrical binder pattern being such that every line drawn parallel to the direction of fiber orientation within a given overlap zone formed by two overlapping columns, intersects at least one elongated area lying predominantly in one column and at least two elongated areas lying predominantly in the other column, within a distance in the direction of fiber orientation equal to the average length of the fibers comprising the web.

10. A web of fibers oriented predominantly in one direction, the fibers lying in parallelism being bonded together by a binder infused into the body of the web in an articulated multisegmental binder pattern, occupying a minor portion of the surface area of said web, said binder pattern comprising a series of parallel, uniformly spaced, broken lines of binder, each line comprising elongated segmental areas of binder separated by intersegmental spaces, substantially free of binder, said parallel lines being inclined obliquely with respect to the direction of fiber orientation.

11. A web of carded fibers substantially all of whose fibers lying in parallelism are bonded together by a binder infused into the body of the web in an articulated multisegmental binder pattern occupying a minor portion of the surface area of said web, said binder pattern

comprising a series of parallel, uniformly spaced, broken lines of binder, each line comprising elongated segmental areas of binder separated by intersegmental spaces that are substantially free of binder, said parallel lines being inclined obliquely with respect to the direction of fiber alignment, said pattern being such that every line parallel to the direction of fiber orientation passes through at least three binder areas within a distance in the direction of fiber orientation equal to the average length of the fiber composing the web.

12. A web of carded fibers substantially all of whose fibers lying in parallelism are bonded together by a binder infused into the body of the web to form a segmental binder pattern occupying only a minor portion of the total lateral surface of the web, said segmental binder pattern comprising a series of parallel, uniformly spaced, broken lines of binder, each line in the series comprising elongated areas of binder uniformly separated by spaces that are substantially free of binder, said parallel broken lines being inclined obliquely with respect to the direction of fiber alignment in the web; a second series of parallel, uniformly spaced broken lines of binder, each line in the second series likewise comprising elongated areas of binder uniformly separated by spaces that are substantially free of binder, said second series of lines also being inclined obliquely with respect to direction of fiber alignment, but in the opposite sense or direction to the lines of said first series; said first series of parallel broken lines being so disposed with respect to said second series of parallel broken lines that the segments of one series lie in the intersegmental spaces of the other series and so that every straight line parallel to the direction of fiber alignment intersects at least three segments within a distance in the direction of fiber orientation equal to the average length of the fibers composing the web.

13. A web of carded fibers substantially all of whose fibers lying in parallelism are bonded together by a binder infused into the body of the web to form a segmental binder pattern occupying a minor portion of the total area of the web, said segmental binder pattern comprising a series of parallel, uniformly spaced, broken lines of binder, each line in the series comprising elongated areas of binder uniformly separated by intersegmental spaces that are substantially free of binder; said parallel lines being inclined obliquely with respect to the direction of fiber alignment in the web; a second series of parallel, uniformly spaced, broken lines of binder, each line in the second series likewise comprising elongated areas of binder uniformly separated by intersegmental spaces that are substantially free of binder; said second series of lines also being inclined obliquely with respect to the direction of fiber alignment, said first series of broken parallel lines being so disposed with respect to said second series of parallel broken lines that the segments of one series lie in the intersegmental spaces of the other series; said segmental pattern, including the angle of inclination of said parallel lines with respect to the direction of fiber alignment, the distance between adjacent lines in each series, the length of and distance between each adjacent segment in each line, and the thickness of each of said segments, being so related that every straight line parallel to the direction of fiber alignment intersects a plurality of segments within the distance in the direction of fiber orientation equal to the average length of the fibers composing the web.

14. The web of claim 13 wherein each of said segments comprise a straight line body portion having terminal portions extending obliquely outwardly from said body portion.

15. The web according to claim 13 wherein said elongated segmental area comprises a closed but elongated, hollow, linear figure.

16. The web of claim 13 wherein said elongated segmental area comprises an annular body portion provided with opposed lateral portions extending outwardly from said body portion.

17. A method of forming a nonwoven fabric from a web of loosely associated, substantially parallelized fibers, which comprises infusing into the body of said web an articulated, multisegmental binder pattern, the individual segments of which are separated from, but hingedly connected to, each other by substantially unbonded lengths of parallelized fibers, said segments be-

11

ing disposed obliquely with respect to the direction of fiber orientation.

18. In the manufacture of an articulated multisegmentally bonded web of substantially parallelized textile fibers, the improvement which comprises positioning a substantial proportion of said segments with their major axes inclined obliquely with respect to said parallelized fibers, thereby imparting elastic recovery properties to the resultant fabric.

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