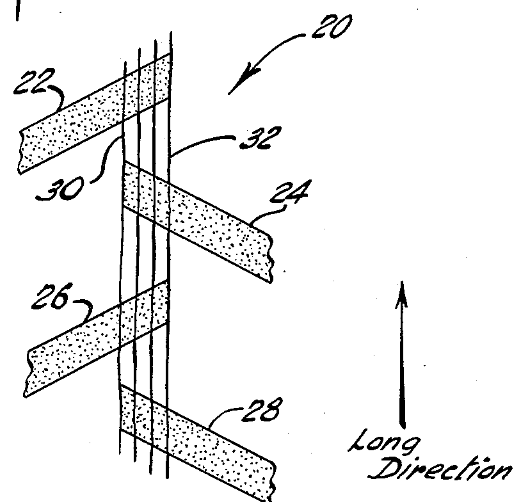
PATTERN BONDED FIBROUS STRUCTURES

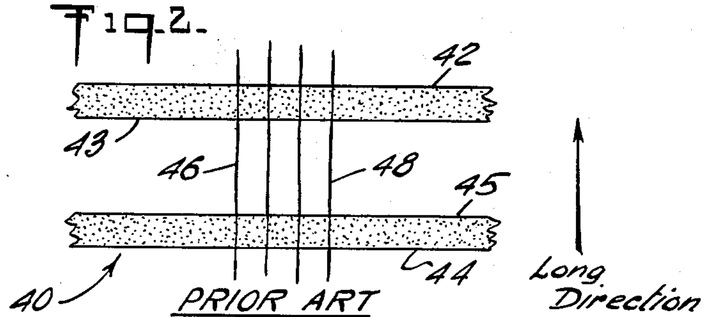
Filed March 19, 1959 4 Sheets-Sheet 1

Fig.1



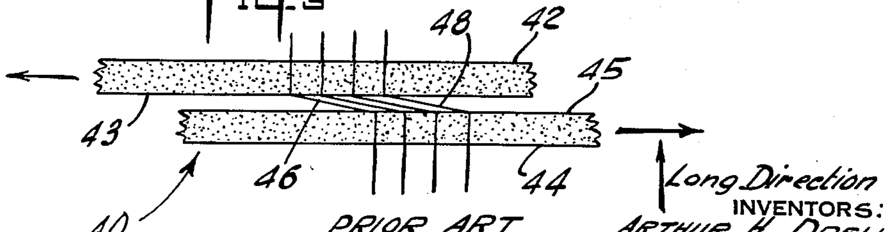
PRIOR ART

Fig.2.



PRIOR ART

Fig.3



PRIOR ART

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Fig. 4.

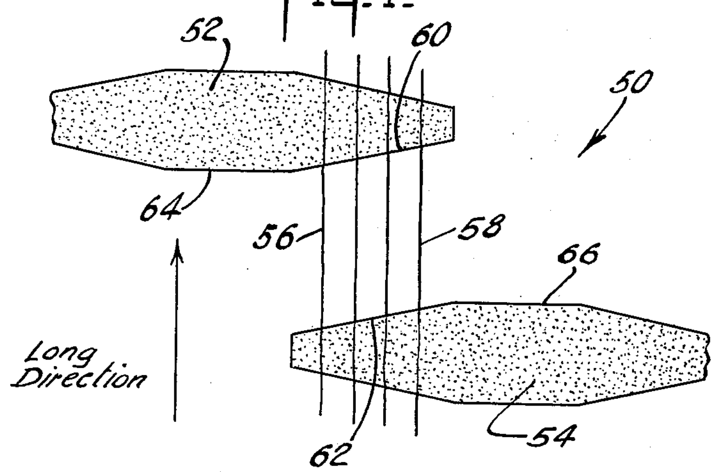


Fig. 5.

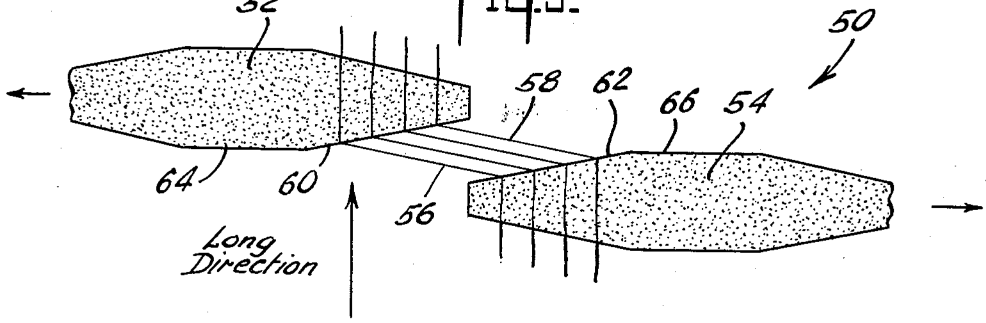
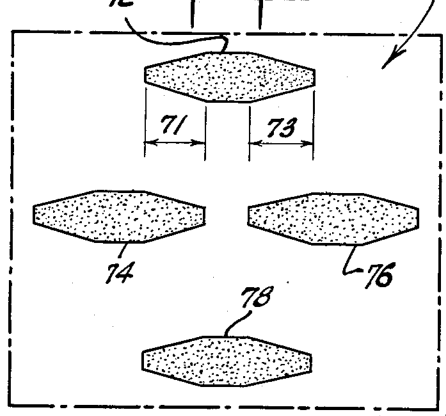


Fig. 6.



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Nov. 21, 1961 A. H. DRELICH ET AL 3,009,823

PATTERN BONDED FIBROUS STRUCTURES

Filed March 19, 1959 4 Sheets-Sheet 3

Fig. 7.

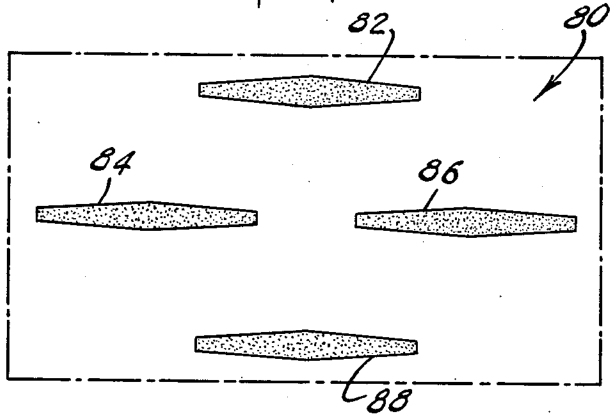


Fig. 8.

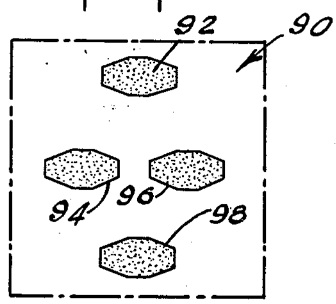
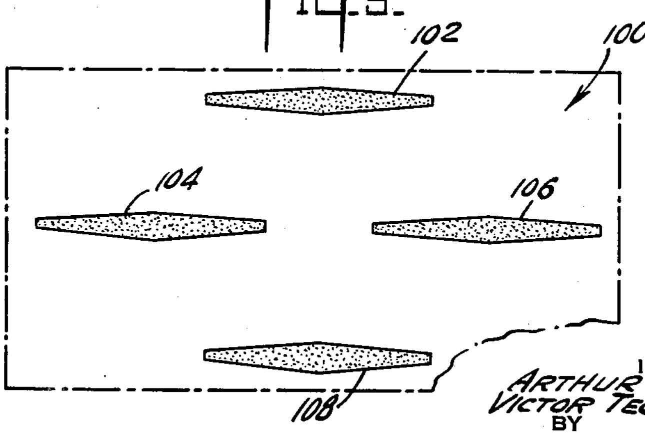


Fig. 9.



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PATTERN BONDED FIBROUS STRUCTURES

Filed March 19, 1959 4 Sheets-Sheet 4

FIG. 10.

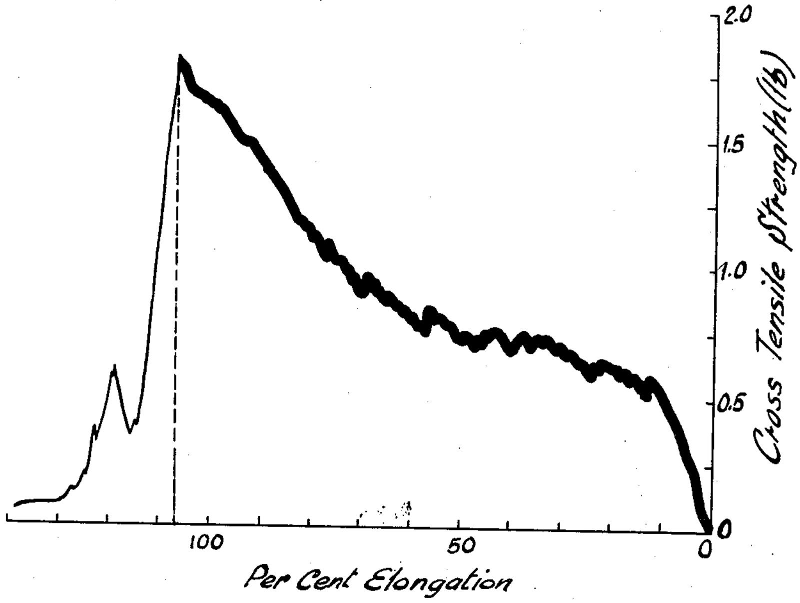


FIG. 11.

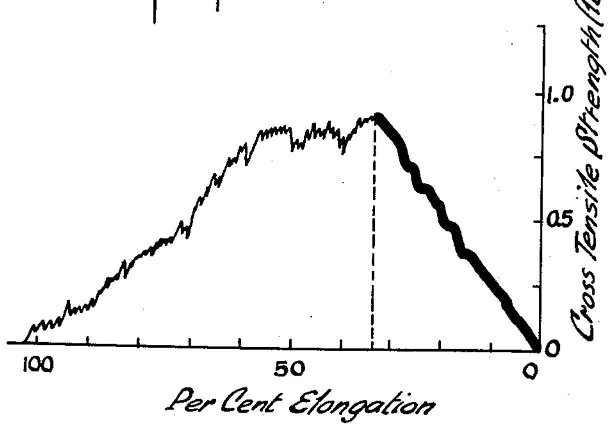
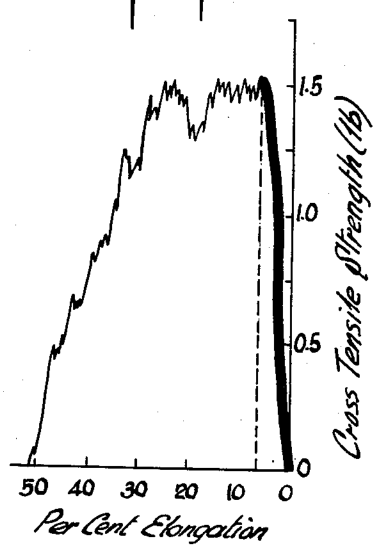


FIG. 12.



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United States Patent Office 3,009,823 Patented Nov. 21, 1961

3,009,823

PATTERN BONDED FIBROUS STRUCTURES

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Filed Mar. 19, 1959, Ser. No. 800,490
7 Claims. (Cl. 117—38)

The present invention relates to nonwoven textile fabrics and more particularly to nonwoven textile fabrics bonded by a pattern of binder areas so arranged as to provide a soft and strong, lint-free, durable nonwoven textile fabric characterized by high cross-tensile strength, high cross elongation, and high energy absorption prior to rupture in the cross direction, even when the base web is oriented predominantly in the long or machine direction.

Bonded nonwoven fabrics of various types have become increasingly important in the textile industry during recent years and their uses have been many and varied, depending naturally upon the basic properties and characteristics of the nonwoven fabric. Notwithstanding the growing importance of such fabrics, very little has been known precisely or scientifically about the planned development of the above-mentioned desirable properties and characteristics of such fabrics.

Various rules of thumb have been followed and considerable trial and error has been resorted to in efforts to build various combinations of softness, durability, and particularly strength, elongation, and energy absorption to rupture in the cross direction of the nonwoven fabric. The necessity for such attention to the cross direction is apparent when it is realized that the orientation of the fibers in the long direction gives to that direction many desired properties notably strength and energy absorption to rupture. The cross direction, however, does not have the advantages of fiber orientation and, consequently, fabric failures due to weaknesses in that direction have been many. Some of these desired properties of strength, elongation, etc., have been obtainable to some degree by using "island" binder segments, more particularly described in U.S. Patents 2,705,686–688, issued April 5, 1955. Such nonwoven fabrics have found acceptance in the industry but the uses thereof have been primarily of the single-use, discardable variety wherein certain properties, notably launderability, are not prerequisites. Considerable effort has been expended in improving the properties and characteristics of such nonwoven fabrics but to date no fundamental understanding is available of the basic underlying cause and creation of the desirable properties and characteristics.

It has now been discovered that the desirable properties of softness, hand and drape may be combined with high cross tensile strength, high cross elongation, and high energy absorption to rupture in the cross direction in nonwoven fabrics by a judicious selection of not only the size, shape and spacing of the binder segments but also their angularity and relationship with respect to the long and cross axes of the nonwoven fabric.

More specifically, it has now been determined that the major weakness of prior nonwoven fabrics lay in the fact that (1) the free unbonded length of adjacent fibers extending in the long direction between two binder segments was not the same and, therefore, when the nonwoven fabric was stretched in the cross direction, for

example, the shorter fibers could not be elongated as far as the longer fibers and consequently would break before the longer fibers could take up their share of the applied cross load. Furthermore, it has also been determined that (2) even if the free unbonded lengths of adjacent fibers extending in the long direction between two binder segments were the same, they did not have complete freedom of movement but cut across or pinched and compressed each other during the application of the cross load, thus decreasing their effective total strength and elongation characteristics, as well as the total energy absorption to rupture.

The basic principle of the present invention is therefore the provision of equal free unbonded lengths of adjacent fibers extending in the long direction between binder segments, so arranged that substantially all the fibers take up bearing loads in the cross direction substantially simultaneously and equally with freedom of movement and without cutting across or pinching and compressing each other during crosswise elongation of the fabric.

In the accompanying drawings and following specification, there are illustrated and described preferred embodiments of the present invention but it is to be understood that the inventive concept is not to be considered limited to the constructions shown except as determined by the scope of the appended claims. Referring to the accompanying drawings, in which:

FIGURE 1 is a fragmentary plan view on an enlarged scale, diagrammatically showing a normal, relaxed portion of a nonwoven fabric having a binder pattern typical of the prior art;

FIGURE 2 is a fragmentary plan view on an enlarged scale, diagrammatically showing a normal, relaxed portion of a nonwoven fabric having another binder pattern typical of the prior art;

FIGURE 3 is a fragmentary plan view on an enlarged scale, diagrammatically showing a portion of the nonwoven fabric of FIGURE 2, stretched or extended in the cross direction;

FIGURE 4 is a fragmentary plan view on an enlarged scale, diagrammatically showing a normal, relaxed portion of a nonwoven fabric having a binder pattern in accordance with a preferred embodiment of the present invention;

FIGURE 5 is a fragmentary plan view on an enlarged scale, diagrammatically showing a portion of the nonwoven fabric of FIGURE 4, stretched or extended in the cross direction;

FIGURES 6 and 7 are fragmentary plan views, on an enlarged scale of approximately 5:1, diagrammatically showing relaxed portions of nonwoven fabrics having binder patterns in accordance with preferred embodiments of the present invention.

FIGURES 8 and 9 are fragmentary plan views, on an enlarged scale of approximately 10:1, diagrammatically showing relaxed portions of nonwoven fabrics having binder patterns in accordance with preferred embodiments of the present invention;

FIGURE 10 is a stress-strain curve of percent cross elongation vs. cross tensile strength of the nonwoven fabric of the present invention illustrated in FIGURE 7;

FIGURE 11 is a stress-strain curve of percent cross elongation vs. cross tensile strength of the nonwoven fabric of the prior art illustrated in FIGURE 1; and

FIGURE 12 is a stress-strain curve of percent cross-elongation vs. cross tensile strength of the nonwoven fabric of the prior art illustrated in FIGURE 2.

In the embodiment of the invention shown in the drawings and with particular reference to FIGURE 1, a relaxed portion of a nonwoven fabric 20 is illustrated wherein the binder pattern is of the "cross-hatch" type. Such a binder pattern is very similar to that illustrated in FIGURE 1 of U.S. Patent 2,705,687, issued April 5, 1955.

In this figure, positions of angularly positioned, discrete binder areas 22, 24, 26 and 28 are shown. With particular reference to binder areas 22 and 24, it is to be observed that there are adjacent fibers extending in the long direction between these two binder areas and bonded thereby. The free unbonded length of these adjacent fibers is not the same and for the purposes of this application, the two end adjacent fibers 30 and 32 will be considered and described in detail. When the nonwoven fabric is stretched in the cross direction, for example, the shorter fiber 30 cannot be elongated as much as the longer fiber 32 and consequently the shorter fiber 30 will bear substantially all of the applied load and will either (1) break before the longer fiber 32 can take up its proportionate share of the applied load or (2) will localize the applied load at one point on the binder area (such as the point at which fiber 30 is bonded to the binder area 22) and rip or tear through the binder area. The former normally occurs when the strength of the binder area is greater than the fiber strength. The latter normally occurs when the strength of the binder area is less than the fiber strength. Such a bonded nonwoven fabric will consequently fail because of (1) fiber breakage or (2) binder area rupture.

It is thus realized that there should be a balancing of the strengths of the binder areas and of the fibers so that the full potential strength of each may be reached without wasting the relatively greater strength of one because of the comparative weakness of the other.

With reference to FIGURE 2, there is illustrated a nonwoven fabric 40 having a binder pattern very similar to that illustrated in U.S. Patent 2,039,312, issued May 5, 1936. The binder pattern essentially comprises binder areas or lines 42, 44, etc., which extend across the nonwoven fabric approximately at a right angle to the long direction. Adjacent fibers including fibers 46 and 48, for example, extend in the long direction between the two binder segments 42 and 44 and have free unbonded lengths which are approximately the same. As a result, when the nonwoven fabric 40 is stretched in the cross direction, for example, and assumes the position shown in FIGURE 3, the fibers 46 and 48 take up the applied loads substantially simultaneously and equally. As a consequence, the possibility of fiber failure is lessened at least to the degree that a few short fibers are not compelled to bear all the load to the benefit of the longer fibers which are not bearing their share of the load, as was present in the preceding case.

However, with particular reference to FIGURE 3, it is to be noted that as the binder area 42 approaches the binder area 44, and their facing sides 43 and 45, respectively, approach each other, the adjacent fibers 46 and 48 are squeezed and pinched together between the binder areas. The angles which these fibers 46 and 48 assume with respect to the sides 43 and 45 of the binder areas 42 and 44 is extremely acute and the bond between the fibers and the binder area is subjected to considerable tearing or ripping action rather than a direct tensional force. Such an action tends to cause binder area failure. Additionally, the fibers are extremely close to each other and tend to cut across each other whereby their effective strength and elongation characteristics are drastically reduced. Such a situation is undesirable and prevents the full development of the strength of both the binder areas and of the fibers.

With reference to FIGURE 4, there is disclosed a nonwoven fabric 50 containing the binder patterns of the present invention. In this figure, binder areas 52 and 54 are provided with adjacent fibers such as 56 and 58 extending in the long direction between these two binder areas.

The unusual torpedo-like shape of each binder area is to be particularly observed. Although the axes of the binder areas extend across the width of the web at approximately a right angle to the long direction, a considerable portion of the sides 60 and 62 of the binder areas are inclined angularly to the axes of their respective binder areas and also to the long axis of the web.

The angle taken by the side 60 of one binder area 52 is the same as the angle taken by the opposed or facing side 62 of the adjacent binder area 54 whereby the sides 60 and 62 are parallel. In this way, the adjacent fibers 56, 58 are parallel and of equal free unbonded length. Consequently, when the nonwoven fabric is stretched in the cross direction, for example, substantially all the fibers take up the bearing load practically simultaneously and equally with relatively few of the fibers showing any tendency to break abnormally before any other fiber.

Additionally, when the nonwoven fabric 50 is stretched in the cross direction, for example, as shown in FIGURE 5, the adjacent fibers 56, 58 will not approach each other to the extent that the adjacent fibers did in FIGURE 3, but will remain at an increased distance from each other whereby there is a significantly decreased tendency for them to cut across or compress each other. This is, of course, due to the angularity of the sides 60 and 62 to which the fibers 56 and 58 are bonded.

Furthermore, it is to be noted that the adjacent fibers 56 and 58 are bonded to the binder areas 52 and 54 and are attached to the sides thereof at an angle which is considerably greater than the angle taken by the fibers and the binder area sides in FIGURE 3. This increased angle reduces the undesirable shearing action on the binder area and thus provides a greater resistance to the cross tensional forces.

In FIGURE 5, it is also to be noted that the side 64 of the binder area 52 has approached and is substantially in direct alignment with the side 66 of the binder area 54, thus indicating in a general way the extent of the elongation. This is to be contrasted to the elongation of the nonwoven fabric in FIGURE 3 wherein the sides 43 and 45 have not reached a direct alignment and, as a matter of fact, cannot reach such a direct alignment due to the resistance offered by the compressed fibers 46 and 48. Such a position of direct alignment could only be reached by the fabric of FIGURE 3 by splitting the binder lines and destroying the utility of the fabric.

It is therefore to be realized that the specific configuration of the binder areas of the present invention is such that the nonwoven fabric can be stretched in the cross direction, for example, with substantially all of the adjacent fibers being elongated to approximately the same extent whereby they can all take up the bearing load substantially simultaneously and equally and without imposing undue tearing forces on the binder areas. Additionally, the adjacent fibers extending in the long direction between the binder areas do not cut across each other and do not pinch or compress each other during the elongation whereby their full potential strength is realized.

In FIGURES 6 through 9, there are illustrated nonwoven fabrics 70, 80, 90 and 100, containing binder areas 72, 74, 76, 78 and 82, 84, 86, 88 and 92, 94, 96, 98 and 102, 104, 106, 108, respectively. These are drawn approximately to a scale which is substantially 5:1 for FIGURES 6 and 7 and 10:1 for FIGURES 8 and 9. It is to be appreciated, however, that although these particular patterns represent specific embodiments of the present inventive concept, they are given primarily for illustrative purposes and are not to be construed as limitative of the present invention.

The geometry of these specific binder areas and five additional typical binder areas is set forth in the following table:

SAMPLE NO.

	Fig. 6	Fig. 7	Fig. 8	Fig. 9	Plate 1	Plate 24	Plate L	Plate Q	Plate O
Bond Length	.275	.120	.180	.180	.254	.090	.220	.160	.140
Gap	.070	.050	.080	.080	.050	.030	.100	.080	.060
Max. Bond Width	.080	.060	.022	.020	.080	.015	.060	.080	.060
Min. Bond Width	.030	.030	.012	.010	.030	.010	.020	.020	.020
Total Overlap, In	.195	.070	.100	.100	.144	.060	.120	.080	.030
Total Overlap, Percent	56.5	41.2	38.5	38.4	47.4	50.0	37.5	33.3	40.0
Lines Per In	4.5	7	10	10	8.33	14.3	6.3	6.3	7.1
Bonds Per In	2.9	5.9	3.8	3.8	3.3	8.3	3.1	8.3	5.0
Bond Area, Sq. In	.01700	.00585	.00306	.00270	.01122	.00113	.01080	.01000	.00600
Surface Coverage, Percent	22.0	24.0	11.8	10.4	31.2	13.4	21.1	26.1	21.4
α	14°2′	23°13′	3°11′	3°11′	2°15′	4°46′	18°25′	36°52′	30°58′
Max. L./Max. W	3.44	2.0	8.2	9.0	3.2	6.0	3.67	2.0	2.0
Interlinear Space	.168	.100	.086	.087	.086	.060	.120	.110	.104

The bond length is the length in inches of each binder area, measured in the cross direction. Bond lengths of from about 0.040 inch to about 0.500 inch have been found satisfactory for the purposes of the present invention. Within the preferred commercial aspects of the present invention, however, bond lengths of from about 0.050 inch to about 0.275 inch have been found preferred.

The gap is the length in inches between adjacent binder areas, measured in the cross direction. Gap lengths of from about 0.020 inch to about 0.200 inch have been found satisfactory for the purposes of the present invention. Within the more commercial aspects of the present invention, however, gap lengths of from about 0.030 inch to about 0.100 inch have been found preferred.

The maximum bond width is the width in inches of the binder area, measured in the long direction, at the widest portion of the binder area. Maximum bond widths of from about 0.012 inch to about 0.150 inch have been found satisfactory for the purposes of the present invention. Within the more commercial aspects of the present invention, however, maximum bond widths of from about 0.015 inch to about 0.100 inch have been found preferred.

The minimum bond width is the width in inches of the binder area, measured in the long direction, at the narrowest portion of the binder area. Minimum bond widths of from about 0.010 inch to about 0.040 inch have been found satisfactory for the purposes of the present invention. Within the more commercial aspects of the present invention, however, minimum bond widths of from about 0.010 inch to about 0.030 inch have been found preferred.

The total overlap in inches is the total length in inches of each binder area which is overlapped by binder areas in an adjacent binder area line. It is measured in the cross direction. Only the length in which parallel, equal-length free, unbonded fibers are present is considered. Reference to FIGURE 6 illustrates that the total overlap length in this figure is the length of line 71 plus the length of line 73. Total overlap length of from about 0.020 inch to about 0.210 inch have been found suitable for the purposes of the present invention. Within the more commercial aspects of the present invention, total overlap lengths of from about 0.060 inch to about 0.195 inch have been found preferred.

The percent overlap is the ratio of the total length of overlap in inches in one line of binder areas to the total width of the nonwoven fabric, measured in the cross direction. Percent overlaps of from about 20% to about 80% have been found suitable for the purposes of the present invention. Within the more commercial aspects of the present invention, from about 33% to about 60% have been found preferred.

The number of lines per inch is the number of lines of binder areas, counted in the long direction of the nonwoven fabric. From about 3 to about 20 lines per inch have been found satisfactory for the purposes of the present invention. Within the more commercial aspects of the present invention, from about 4 to about 16 lines per inch have been found preferred.

The number of bonds per inch is the number of bonds per inch of binder area line measured in the cross direction of the nonwoven fabric. From about 2⅓ bonds per inch to about 15 bonds per inch has been found suitable for the purposes of the present invention. Within the more commercial aspects of the present invention, about 3 to about 12 bonds per inch have been found preferred.

The bond area is the area in square inches of an individual binder area. Bond areas of from about 0.0010 square inches to about 0.025 square inch have been found suitable for the purposes of the present invention. Within the more commercial aspects of the present invention, bond areas of from about 0.0027 square inch to about 0.017 square inch have been found preferred.

The surface coverage is the percentage of area of nonwoven fabric covered with binder areas with respect to the total area of the nonwoven fabric being bonded. Surface coverages of from about 8% to about 35% have been found suitable for the purposes of the present invention. Within the more commercial aspects of the present invention, however, surface coverages of from about 10% to about 32% have been found preferred.

The angle α is the angle of the side of the binder area with respect to the axis of the line of binder areas. Angles of from about 2° to about 40° have been found satisfactory for the purposes of the present invention. Within the more commercial aspects of the present invention, angles of from about 3° to about 30° have been found preferred. Angles above 40° and particularly those about 45° are not desirable for the purposes of the present invention.

The ratio of the maximum length to the maximum width is the ratio of the maximum length in inches of the binder area to the maximum width in inches of the binder area. Ratios of from about 2:1 to about 12:1 have been found suitable for the purposes of the present invention. Within the more commercial aspects of the present invention, however, ratios of from about 2:1 to about 10:1 have been found preferred.

The interlinear space is the minimum distance in inches of the clear space between adjacent lines of binder areas. This is measured in the long direction and extends between the most closely adjacent points on adjacent binder areas. Interlinear spaces of from about 0.040 inch to about 0.220 inch have been found suitable for the purposes of the present invention. Within the more commercial aspects of the present invention, however, interlinear spaces of from about 0.060 inch to about 0.180 inch have been found preferred.

The conventional base starting material for nonwoven fabrics is a fibrous web comprising any of the common textile-length fibers, or mixtures thereof, the fibers varying in average length from approximately one-half inch to about two and one-half inches. Exemplary of such fibers are the natural fibers such as cotton and wool and the man-made cellulosic fibers, notably rayon or regenerated cellulose. These fibers, or mixtures thereof, if they are of textile length, are customarily processed through any suitable textile machinery (e.g., a conventional cotton card or other fibrous web producing apparatus) to form a web or sheet of loosely associated fibers, weighing from about 100 grains to about 2000 grains per square yard or even higher. This essentially two-dimensional web or sheet of fibers is produced continuously with the fibers generally predominantly oriented in the "machine direction," i.e., the direction in which the web is formed and is moved continuously from the sheet-forming machine. In such a web, the degree of orientation, or the ratio of oriented to non-oriented fibers in the machine direction, may be described for purposes of simplicity as varying roughly from about 60% to about 90%, that is to say that from about 60% to about 90% by weight of the fibers are substantially oriented or aligned more or less in the machine direction and from about 10% to about 40% by weight of the fibers are non-oriented in the machine direction and lie in overlapping, intersecting relationship.

While the patterns described herein may be used to some advantage on non-oriented webs, such as webs prepared by methods involving air-laying or deposition from water, their greatest utility is in oriented web structures since these patterns impart a degree of cross tensile and toughness, combined with good handle and drape otherwise not obtainable with oriented webs.

The particular type of binder used in printing the nonwoven web is preferably of the non-migratory type. Such a binder, under the printing conditions used, will not migrate or spread more than about 100% and preferably less than 40% of the original width of the applicator print pattern and will show relatively clear cut and sharp boundaries between bonded and bond free portions. This value of 40% is actually a relatively low value when it is realized that other binders, not of the non-migratory type, will migrate up to 200% or more of the originally printed area. Illustrative of such non-migratory binders is regenerated cellulose or viscose.

The amount of solid binder add-on will vary within relatively narrow limits depending upon the chemical nature, the solids content, the viscosity and other rheological characteristics of the binder, the thickness and weight of the nonwoven web, the surface area and depth of engraving of the particular binder pattern being used, and so forth. It may be as low as about 1 percent and may be as high as about 10 percent by weight of the dry nonwoven web for the preferred binder which is regenerated cellulose.

The invention will be further illustrated in greater detail by the following specific examples. It should be understood, however, that although these examples may describe in particular detail some of the more specific features of the invention, they are given primarily for purposes of illustration and the invention in its broader aspects is not to be construed as limited thereto.

Example I

The binder pattern illustrated in FIGURE 6 of the drawings and described in the table in the specification is employed on a card web comprising 1.5 denier, 1 9/16 inches staple length viscose rayon and weighing about 1100 grains per square yard. The binder is viscose which is printed on the fabric as cellulose xanthate and regenerated into viscose by conventional procedures. The depth of the engraving on the printing roller is 0.014 inch. The resulting fabric is useful as a drapery fabric.

The physical properties of the above-mentioned fabric are evaluated on an Insco Tester, a constant rate of extension type tensile tester. Testing is done according to the following specifications: 1 inch sample width; 2 inches jaw spacing; 2 inches per minute jaw speed; and 4 inches per minute chart speed. The nonwoven fabric has a tensile strength of approximately 3.9 pounds per 1 inch sample width, measured in the cross direction. Its cross elongation at break is about 79%.

Example II

The binder pattern illustrated in FIGURE 7 of the drawings and described in the table in the specification is employed on a card web comprising 1.5 denier, 1 9/16 inches staple length viscose rayon and weighing about 600 grains per square yard. The binder is viscose which is printed on the fabric as cellulose xanthate and regenerated into viscose by conventional procedures. The depth of the engraving on the printing roller is 0.010 inch. The resulting fabric is useful as a hand towel.

This fabric has a cross tensile strength of 1.8 pounds per 1 inch sample width. Its cross elongation at break is approximately 105%. Method of testing is substantially the same as described in Example I. These results are shown graphically in FIGURE 10.

These values are to be contrasted to those which are obtained for a nonwoven fabric made of the same fibers but weighing 679 grains per square yard and viscose bonded with the pattern shown in FIGURE 1. Such a comparison sample has a cross tensile strength of only 0.87 pound per 1 inch sample width. Its cross elongation at break is approximately only 33%. Method of testing is substantially as described in Example I. The results are shown graphically in FIGURE 11.

A comparison is also made to a nonwoven fabric bonded with viscose in a line pattern such as illustrated in FIGURE 2. In this pattern, there are 8 lines per inch, with each line 0.022 inch wide and at an angle of 80° to the long axis. The fabric weight is 650 grains per square yard. The nonwoven fabric has a cross tensile strength of only 1.5 pounds per 1 inch sample width. Its cross elongation at break is approximately only 5%. Method of testing is substantially as described for Example I. The results are shown graphically in FIGURE 12.

Example III

The binder pattern illustrated in FIGURE 8 of the drawings and described in the table in the specification is employed on a card web comprising 1.5 denier, 1 9/16 inches staple length viscose rayon and weighing about 200 grains per square yard. The binder is viscose which is printed on the fabric as cellulose xanthate and regenerated into viscose by conventional procedures. The depth of the engraving on the printing roller is 0.004 inch. The resulting fabric is useful as a cover for sanitary napkins.

This fabric has a cross tensile strength of 0.3 pound per 1 inch sample width. Its cross elongation at break is approximately 80%. Method of testing is substantially the same as described in Example I.

Example IV

The binder pattern illustrated in FIGURE 9 of the drawings and described in the table in the specification is employed on a card web comprising 1.5 denier, 1 9/16 inches staple length viscose rayon and weighing about 200 grains per square yard. The binder is viscose which is printed on the fabric as cellulose xanthate and regenerated into viscose by conventional procedures. The depth of the engraving on the printing roller is 0.004 inch. The resulting fabric is useful as a cover for sanitary napkins.

This fabric has a cross tensile strength of 0.34 pound per 1 inch sample width. It has a cross elongation at break of approximately 25%. Method of testing is substantially the same as described in Example I.

Examples V, VI, VII and VIII

The procedures set forth in Examples I through IV are followed substantially as set forth therein with the exception that the card web comprises middling American Upland cotton fibers rather than the viscose rayon fibers. The resulting bonded nonwoven fabrics find uses similar to those set forth in the respective Examples I through IV.

Examples IX, X, XI and XII

The procedures set forth in Examples I through IV are followed substantially as set forth therein with the exception that the card web comprises 50% by weight of 1.5 denier, 1$\frac{9}{16}$ inches staple length bright viscose rayon and 50% by weight of middling American Upland cotton fibers. The resulting fabrics are comparable to the fabrics obtained in Examples I through IV.

The unusual characteristics and properties created in nonwoven fabrics by the print patterns of the present invention are shown in FIGURES 10 through 12. These are stress-strain curves obtained by the procedures described in Example I.

In FIGURE 10 there is graphically illustrated the stress-strain curves of the nonwoven fabric of Example II weighing 600 grains per square yard. Reading from the right to the left on the curve, it is noted that the cross tensile stress increases rapidly during the initial 10% elongation of the fabric. Stretching and softening continue to take place up to about 90% elongation, during which some fibers which are not oriented substantially parallel to the machine direction are broken. But, that does not affect the breaking load of the fabric in any way. This can be proved by the fact that if you stop elongating the nonwoven fabric at 90% elongation and remove the applied stress, and then reload the sample to the rupture point, the fabric still yields a breaking load of 1.8 pounds. Beyond 90% elongation, the stray fibers are substantially broken. The parallel fibers under the overlap lengths align themselves and combine to take up the load. The cross tensile stress goes up to 1.8 pounds and the fabric ruptures abruptly.

In FIGURE 11 there is illustrated the stress-strain curve of the prior art nonwoven fabric of Example II weighing 679 grains per square yard and illustrated in FIGURE 1. In this nonwoven fabric, elongation is constant and is accompanied by the breaking of a considerable number of fibers. The maxium strength is reached at only 0.87 pound and the fabric gradually ruptures from that point on. It is to be pointed out although the total percent elongation is over 100%, that part of the elongation beyond about 33% is of no practical value inasmuch as the nonwoven fabric has ruptured at 33%.

In FIGURE 12 there is graphically illustrated the stress-strain curve of the prior art nonwoven fabric of Example II weighing 650 grains per square yard and bonded with the pattern of FIGURE 2. In this curve it is to be noted that the cross tensile strength is relatively good due to the fact that the bonding areas extend substantially directly across the nonwoven fabric and are capable of resisting the applied stress. The cross tensile strength is 1.5 but it is to be noted that the percent elongation is extremely low and is only 5%. Following the rupture of the fabric, beyond which point it possesses no practical value, the curve irregularly falls off to 0.

It is also to be appreciated that the total energy absorption to break in the cross direction is measured by the area under the curve up to the point of rupture. The very large area under the curve of FIGURE 10, is to be contrasted to the relatively small areas under the curves of FIGURES 11 and 12. In such comparison only the areas under the curve up to the point of rupture should be considered inasmuch as all the fabrics have no practical value after their points of rupture. The increase in energy absorption prior to rupture in the cross direction of the invention nonwoven fabric is sharply illustrated in these figures.

Although several specific examples of the inventive concept have been described, the same should not be

construed as limited thereby nor to the specific features mentioned therein but to include various other equivalent features as set forth in the claims appended hereto. It is understood that any suitable changes, modifications and variations may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A web of fibers oriented predominantly in one direction, the fibers being bonded by a pattern of elongated binder areas lying in a series of substantially parallel lines, the axes of said binder areas and said lines extending across the width of the web, each of said binder areas having sides which are inclined angularly from about 2° to about 40° in a clockwise direction to the axes of said lines of binder areas and other sides which are inclined angularly from about 2° to about 40° in a counterclockwise direction to the axes of said lines of binder areas, said angularly inclined sides being substantially parallel to the angularly inclined sides of binder areas in adjacent lines, said binder areas being relatively elongated in a direction across the width of said web and having a length to width ratio of from about two to one to about twelve to one whereby fibers bonded to adjacent binder areas in adjacent binder lines have substantially equal free unbonded lengths extending between said adjacent binder areas whereby forces tending to elongate the web in a cross direction are resisted substantially equally by the substantially equal free unbonded lengths of the fibers extending between said adjacent binder areas.

2. A web of fibers oriented predominantly in one direction, the fibers being bonded by a pattern of elongated binder areas lying in a series of substantially parallel lines, the axes of said binder areas and said lines extending across the width of the web, each of said binder areas having a major portion of their sides inclined angularly to the axes of said lines of binder areas, a part of said sides being inclined angularly from about 2° to about 40° in a clockwise direction to the axes of said lines of binder areas and another part of said sides being inclined angularly from about 2° to about 40° in a counterclockwise direction to the axes of said lines of binder areas, said angularly inclined sides being substantially parallel to the sides of binder areas in adjacent lines, said binder areas being relatively elongated in a direction across the width of said web and having a length to width ratio of from about two to one to about twelve to one whereby fibers bonded to adjacent binder areas in adjacent binder lines have substantially equal free unbonded lengths extending between said adjacent binder lines whereby forces tending to elongate the web in a cross direction are resisted substantially equally by substantially equal free unbonded lengths of the fibers extending between said adjacent binder areas.

3. A web of fibers oriented predominantly in one direction, the fibers lying in substantial alignment being bonded by a uniform pattern of elongated binder areas occupying a minor portion of the surface of the web, said binder areas lying in a series of substantially parallel lines, the axes of said binder areas and said lines extending across the width of the web, each of said binder areas having sides which are inclined angularly from about 2° to about 40° in a clockwise direction to the axes of said lines of binder areas and other sides which are inclined angularly from about 2° to about 40° in a counterclockwise direction to the axes of said lines of binder areas, said angularly inclined sides being substantially parallel to the sides of binder areas in adjacent lines, said binder areas being relatively elongated in a direction across the width of said web and having a length to width ratio of from about two to one to about twelve to one whereby fibers bonded to adjacent binder areas in adjacent binder lines have substantially equal free unbonded lengths extending between said adjacent binder areas whereby forces tending to elongate the web in a cross direction are resisted substantially equally by the substantially

equal free unbonded lengths of the fibers extending between said adjacent binder areas.

4. A web of fibers oriented predominantly in one direction, the fibers being bonded by a pattern of elongated binder areas lying in a series of substantially parallel lines, the axes of said binder areas and said lines substantially coinciding and extending across the width of the web, each of said binder areas having sides which are inclined angularly from about 2° to about 40° to the axes of said lines of binder areas and which are substantially parallel to the sides of binder areas in adjacent lines whereby fibers bonded to adjacent binder areas in adjacent binder lines have substantially equal free unbonded lengths extending between said adjacent binder areas whereby forces tending to elongate the web in a cross direction are resisted substantially equally by the substantially equal free unbonded lengths of the fibers extending between said adjacent binder areas.

5. A web of fibers oriented predominantly in one direction, the fibers being bonded by a pattern or elongated binder areas lying in a series of substantially parallel lines, the axes of said binder areas and said lines substantially coinciding and extending across the width of the web, each of said binder areas having sides which are inclined angularly from about 2° to about 40° to the axes of said lines of binder areas and which are substantially parallel to the sides of binder areas in adjacent lines, said binder areas being relatively elongated in a direction across the width of said web and having a length to width ratio of from about two to one to about twelve to one whereby fibers bonded to adjacent binder areas in adjacent binder lines have substantially equal free unbonded lengths extending between said adjacent binder areas whereby forces tending to elongate the web in a cross direction are resisted substantially equally by the substantially equal free unbonded lengths of the fibers extending between said adjacent binder areas.

6. A web of fibers oriented predominantly in one direction, the fibers being bonded by a pattern of elongated binder areas lying in a series of substantially parallel lines, the axes of said binder areas and said lines extending across the width of the web, each of said binder areas having end portions which are tapered and sides which are inclined angularly from about 2° to about 40° to the axes of said lines of binder areas, said angularly inclined sides being substantially parallel to the angularly inclined sides of binder areas in adjacent lines whereby fibers bonded to adjacent binder areas in adjacent binder lines have substantially equal free unbonded lengths extending between said adjacent binder areas whereby forces tending to elongate the web in a cross direction are resisted substantially equally by the substantially equal free unbonded lengths of the fibers extending between said adjacent binder areas.

7. A web of fibers oriented predominantly in one direction, the fibers being bonded by a pattern of elongated binder areas lying in a series of substantially parallel lines, the axes of said binder areas and said lines extending across the width of the web, each of said binder areas having end portions which are tapered and sides which are inclined angularly from about 2° to about 40° to the axes of said lines of binder areas, said binder areas also having central portions which are thicker than said tapered end portions, said angularly inclined sides being substantially parallel to the angularly inclined sides of binder areas in adjacent lines whereby fibers bonded to adjacent binder areas in adjacent binder lines have substantially equal free unbonded lengths extending between said adjacent binder areas whereby forces tending to elongate the web in a cross direction are resisted substantially equally by the substantially equal free unbonded lengths of the fibers extending between said adjacent binder areas.

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