July 19, 1960 C. HARMON ET AL 2,945,283

MACHINE FOR AND METHOD OF CROSS STRETCHING NONWOVEN WEBS

Filed Oct. 30, 1956 4 Sheets-Sheet 1

FIG. 1

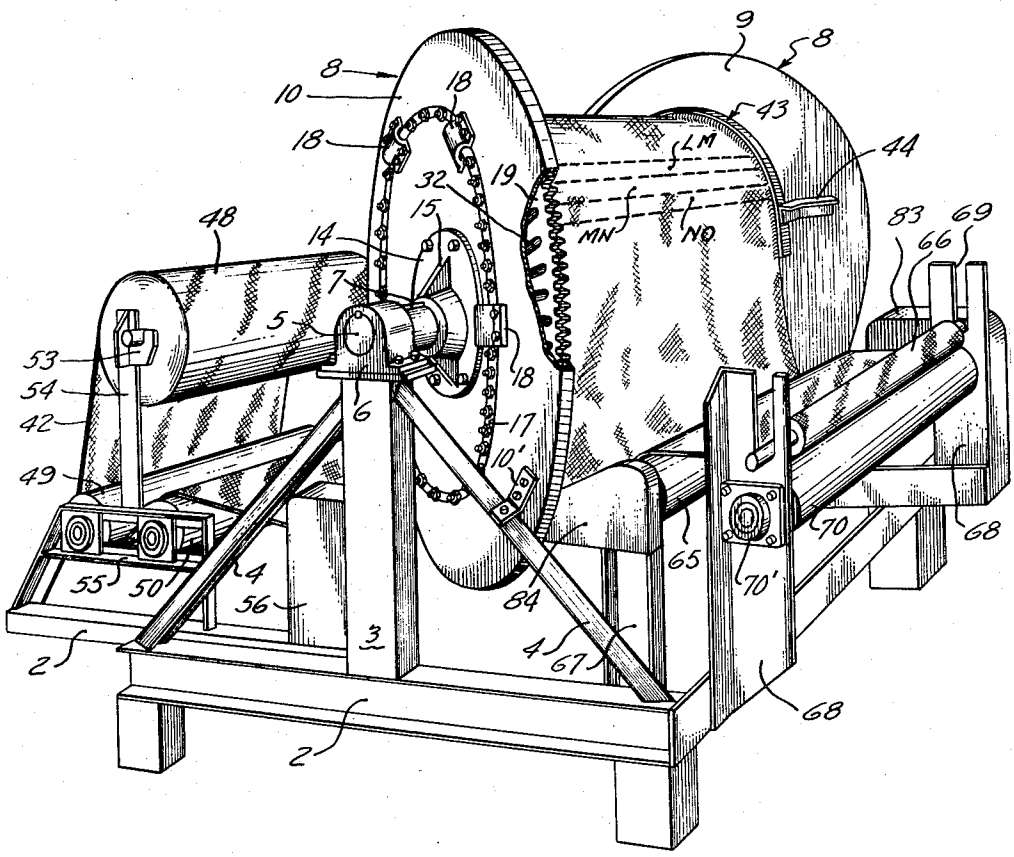


FIG. 8

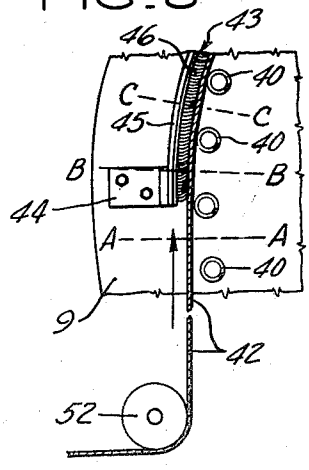
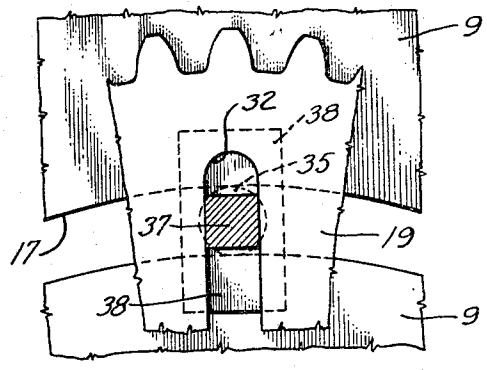


FIG. 7



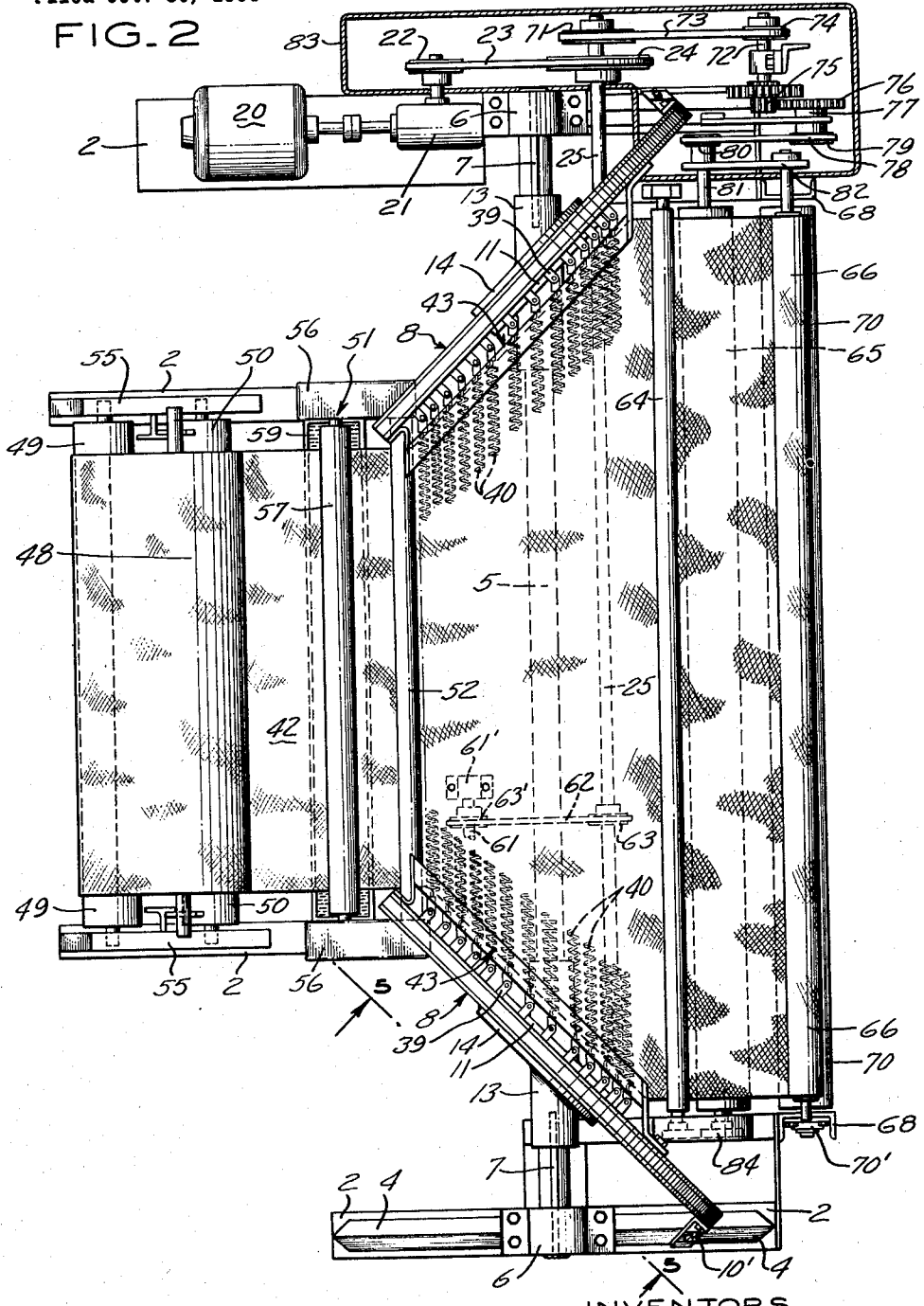
INVENTORS
CARLYLE HARMON
FRANKLIN WELLS SHOEMAKER
BY Schneider, Dressler & Goldsmith
ATTORNEYS

July 19, 1960 C. HARMON ET AL 2,945,283

MACHINE FOR AND METHOD OF CROSS STRETCHING NONWOVEN WEBS

Filed Oct. 30, 1956 4 Sheets-Sheet 2

FIG. 2



INVENTORS
CARLYLE HARMON
FRANKLIN WELLS SHOEMAKER
BY Schneider, Dressler & Goldsmith.
ATTORNEYS

July 19, 1960 C. HARMON ET AL 2,945,283

MACHINE FOR AND METHOD OF CROSS STRETCHING NONWOVEN WEBS

Filed Oct. 30, 1956 4 Sheets-Sheet 3

FIG. 3

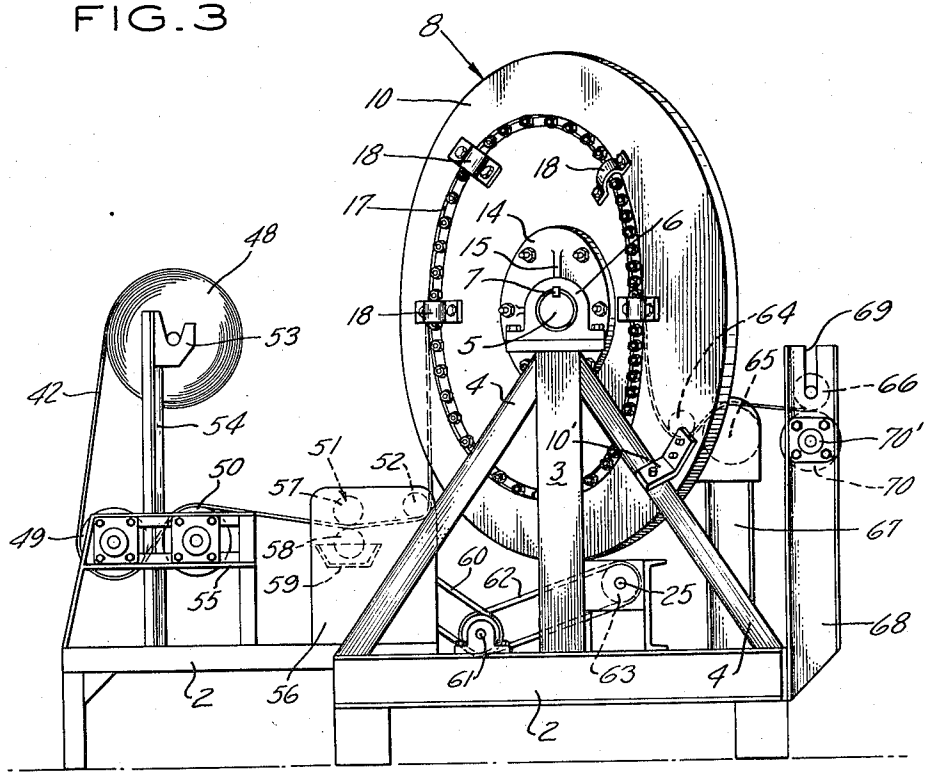
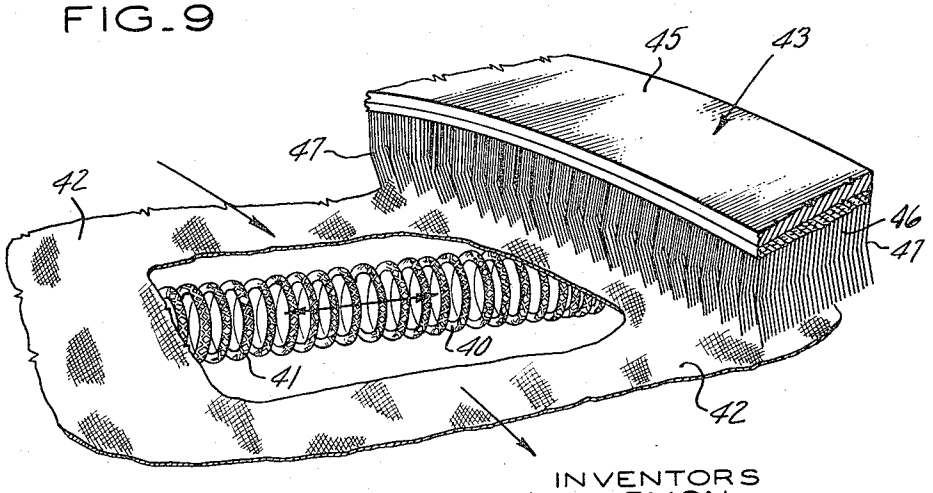


FIG. 9



INVENTORS
CARLYLE HARMON
FRANKLIN WELLS SHOEMAKER
BY Schneider, Pressler & Goldsmith
ATTORNEYS

July 19, 1960 C. HARMON ET AL 2,945,283

MACHINE FOR AND METHOD OF CROSS STRETCHING NONWOVEN WEBS

Filed Oct. 30, 1956 4 Sheets-Sheet 4

FIG. 4

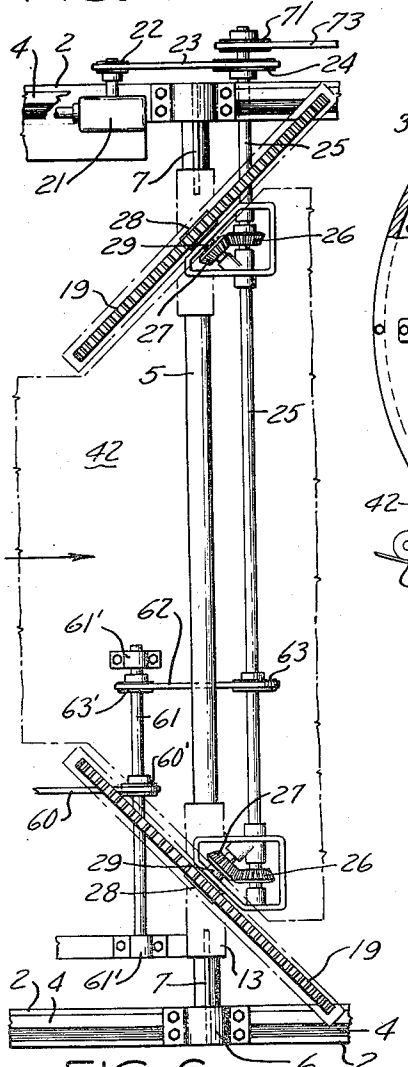


FIG. 5

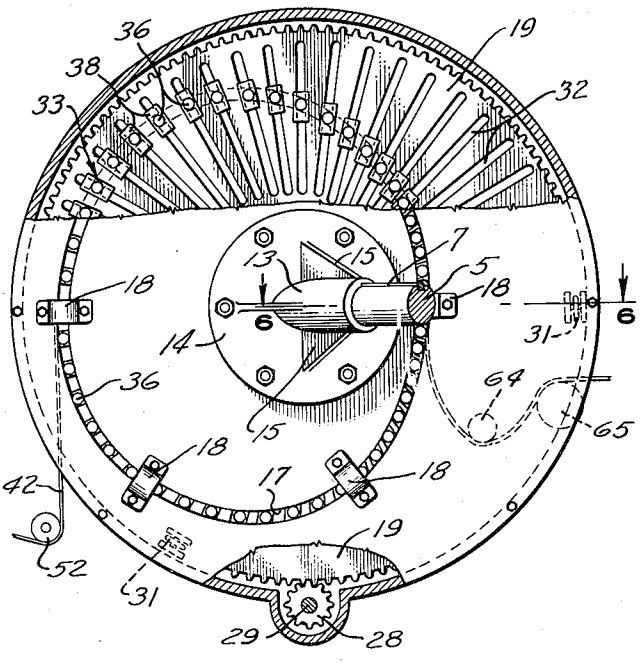


FIG. 10

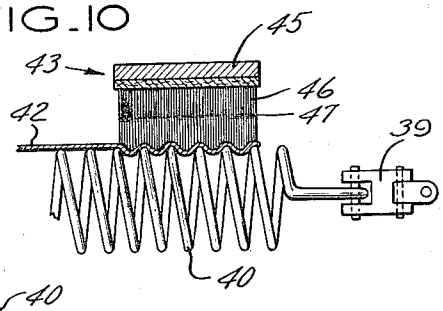
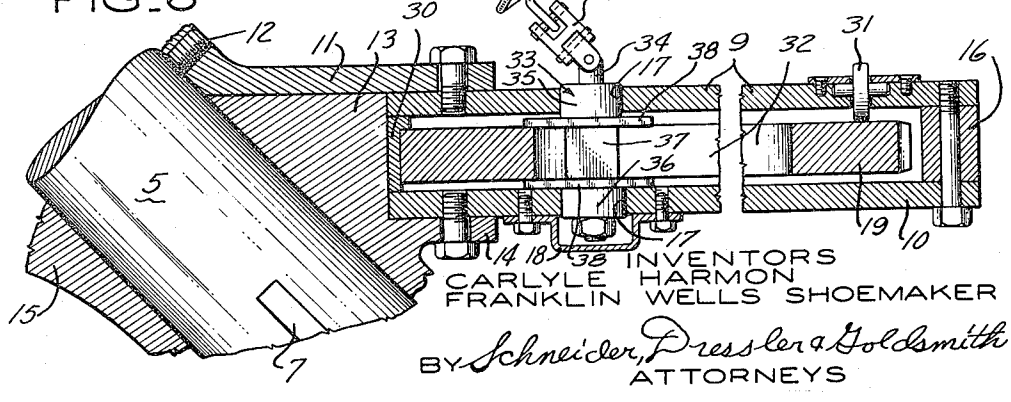


FIG. 6



INVENTORS
CARLYLE HARMON
FRANKLIN WELLS SHOEMAKER
BY Schneider, Pressler & Goldsmith
ATTORNEYS

United States Patent Office 2,945,283 Patented July 19, 1960

2,945,283

MACHINE FOR AND METHOD OF CROSS STRETCHING NONWOVEN WEBS

Carlyle Harmon, Scotch Plains, and Franklin Wells Shoemaker, Princeton, N.J., assignors to Chicopee Manufacturing Corporation, a corporation of Massachusetts

Filed Oct. 30, 1956, Ser. No. 619,289

25 Claims. (Cl. 28—76)

This invention relates to a machine for and method of transversely stretching and longitudinally shrinking webs of nonwoven fibers, and in its preferred form involves such a machine and method capable of simultaneously effecting cross stretching and long shrinking of a web of nonwoven fibers in such a way that the unit web weight remains substantially constant as these two dimensional changes are effected.

Briefly, the present invention involves cross stretching a nonwoven web of fibrous material, in which the fibers are generally oriented in a longitudinal direction, to move the individual fibers from their original parallelism to positions in which the average angle between the fibers and said longitudinal direction is increased, and simultaneously long shrinking the web. In the preferred form of the invention, the cross stretching and long shrinking are controlled in amount so that the web area, and thus the web density (i.e., unit web weight throughout the area of the web), are kept constant.

Conventional nonwoven fabrics

Nonwoven fabrics are conventionally manufactured at the present time by producing a more or less tenuous web of loosely associated textile fibers disposed in sheet form (using any one of a variety of well-known procedures) and then bonding the sheet or web, to anchor or bond the individual fibers together. The conventional base material for such nonwoven fabrics is a web comprising any of the common textile-length fibers or mixtures thereof, the fibers varying from approximately one-fourth to one-third of an inch as the lower limit to approximately two or more inches in staple length. These fibers are customarily processed into web form by one of two general techniques, i.e., carding, or the like, to form an "oriented" web, or air laying to form an "isotropic" web.

"Oriented" webs are made by passing the fibers through a conventional card to form a web or sheet of loosely associated fibers, and then superposing a plurality of these webs to provide a laminated web weighing approximately from 100 to 5000 grains per square yard. This web or sheet of fibers is produced continuously with most of the fibers substantially parallelized or oriented in the "machine direction," i.e., in the direction in which the product moves continuously from the sheet-forming machine. A web possessing substantially uniform density, wherein the fibers are distributed substantially uniformly throughout the area of the web, can be produced at relatively high speeds by this technique.

Fiber orientation

In a web produced as just described, it is difficult to measure fiber orientation directly because the individual fibers thereof are curled and bent, with various segments of the fibers extending in various directions. However, a kind of average orientation may be ascertained which is helpful in describing the physical characteristics of the web. This characteristic is called the "degree of fiber orientation." The "degree of fiber orientation" is determined by bonding the web uniformly with a material such as starch, drying the bonded web, measuring tensile strengths lengthwise and crosswise of the resulting fabric, and then computing the percentage of lengthwise or long strength of the fabric to its total strength. Total strength, for this purpose, is the sum of the tensile strengths in the long and cross directions. Thus, when long and cross tensile strengths are equal, the "degree of fiber orientation" is 50 percent.

Something more can be said generally about the positions in which the various fibers lie in the plane of the web. In a web wherein most of the fibers are substantially parallelized along the longitudinal axis of the web, the average angle between that axis and most of the individual fibers of the web is substantially zero. When an individual fiber is reoriented by the method of this invention to be described below, it is generally moved into a new position in which the angle it makes with the longitudinal axis of the web is increased. Thus, the combined effect of the movement of all the fibers that are reoriented in the web is to increase the average angle between the longitudinal axis of the rearranged web and all the various fibers contained in the web.

Disadvantages of known nonwoven fabrics

The bonding operation by which an oriented web is converted into a fabric may be accomplished in one of several different ways. For example, one method is to impregnate the web over its entire width with various well-known bonding agents such as natural or synthetic resins. Another method is to print nonwoven webs with continuous straight or wavy lines of binder extending transversely or obliquely across the web. Still another method is to imprint on the web a discontinuous binder pattern, consisting of discrete, physically separated areas of binder, arranged in a staggered pattern.

Regardless of the bonding method used in producing a fabric directly from a web of oriented textile fibers, fabrics so formed have been subject to a major disadvantage: the starting web, and thus also the resulting fabric, are "nonisotropic" in respect to their physical properties. In particular, the tensile strength of the resulting fabric transverse to the direction of fiber orientation (its "cross strength"), is very much less than the tensile strength of the fabric in a direction parallel to the fiber orientation (its "long strength"). As a result, oriented nonwoven fabrics heretofore have been characteristically weak in the cross direction, tending to rip or tear when the web is subjected to even a moderate cross extensional stress.

Various techniques have been proposed for forming webs wherein the fiber orientation is more or less random. These webs may be bonded to form "isotropic" nonwoven fabrics wherein the long and cross strengths are approximately equal. Conventionally, the fabrics are dispersed in an air stream which is flowed through a continuously moving foraminous collecting member which in turn separates and removes the fibers from the stream. The fibers are deposited on the collecting member in the form of a web or layer which may be removed therefrom for bonding purposes.

Since in air-laying, positive mechanical control of the fibers is not maintained during the time they are being carried in a stream or projected to the collecting member, considerable difficulty has been experienced in attempting to obtain a web having a uniform fiber distribution. This is particularly true of light-weight webs wherein lack of uniformity will result in serious local weaknesses and even holes. While attention has been given to this difficulty in connection with the methods and apparatus disclosed in Plummer et al., United States Patents 2,676,363 and 2,676,364, the basic problem of controlling web uniformity is inherent in air deposition

systems, particularly at normal economical production speeds for fabrics of this type.

Method of this invention

In accordance with the present invention an unbonded web having a substantially uniform density throughout the area thereof formed of loosely associated textile fibers, such as a carded web made from a multiplicity of superposed conventional card webs, which carded web weighs from approximately 100 to 5000 grains per square yard, in which the fibers are predominantly parallelized or oriented in the long direction, is subjected to a combined cross stretching and longitudinal shrinking operation to move the originally parallelized fibers into a reoriented arrangement with the average angle between individual fibers and the longitudinal axis of the web increased.

The cross stretching is effected in a direction substantially normal to the original direction of fiber orientation while the shrinking is effected in the said original direction of fiber orientation, i.e., the length of the web. This operation results in a deformation of the web in the plane thereof, increasing its dimensions transverse to the direction of the originally parallelized fibers and decreasing its dimensions in the long dimension.

Changes in web characteristics

During this web deformation, the fibers in the web are moved into reoriented positions, but in their new positions they still remain individually intermingled, overlapping and crossing other individual fibers in the web in frictional and mechanical engagement therewith.

The reoriented web formed by the combined cross stretching and long shrinking operation of the present invention, and then bonded to form a reoriented, nonwoven fabric, brings about in the said fabric an increase in the strength of the fabric in the cross direction (the width), i.e., transverse to the direction of the originally parallelized fibers in the web. In other words, the reoriented web has the potential of being converted by bonding into a nonwoven fabric having an increased tensile strength in the cross direction as compared to the oriented nonwoven fabrics of the prior art.

The term "potential" tensile strength as applied to a web in the following description refers to the tensile strength of the fabric formed by bonding the fibers of the web into a unitary structure. The cross strength of the fabric is increased to the extent that the originally parallelized fibers in the web are moved or oriented away from the parallel.

In the reoriented web the density is substantially uniform throughout the area thereof regardless of the thickness of the web or the speed at which it is produced. The preferred reoriented web is one wherein the average angle between individual fibers and the longitudinal axis of the web is increased to the point where the "degree of fiber orientation" is reduced to approximately 50 percent. A web approaching this preferred form in structure is capable when bonded of providing a long-to-cross tensile strength ratio of approximately one. This preferred web may be called a "pseudo-isotropic" web, because its potential tensile strength is of the same general order of magnitude in all directions, being in fact substantially equal when measured along the two major axes at 90° to each other, i.e., the longitudinal and transverse axes of the web. Thus, the rearranged fiber web acts very much like a true "isotropic" web, and may for this reason be referred to as a "pseudo-isotropic" web.

As the fibers of the original oriented web are reoriented to reduce the "degree of fiber orientation," the increased width of the web tends to be more or less compensated for by the accompanying long shrinking thereof, with the result that the reoriented pseudo-isotropic web may have an area substantially the same as the area of the starting conventional card web. In the preferred form

of the invention, the amount of long shrinking is controlled to compensate as nearly as possible for the cross stretching, so as to keep the web area and web density substantially constant.

Starting webs

Although the machine of the present invention is primarily designed for cross stretching and long shrinking unbonded webs of nonwoven fibers, it can also be used to perform these operations on prebonded nonwoven webs.

The web may comprise natural fibers, such as cotton, wool, jute, ramie, or abaca, or artificial fibers of viscose rayon, cuprammonium rayon, cellulose acetate, nylon, dynel, or other materials, either alone or in combination with one another. The length of the individual fibers depends upon the ultimate purpose for which the web is intended. Regardless of the specific fibers used, the frictional resistance between the individual fibers should be low enough to permit rearrangement of the fibers in the plane of the web without rupture of the web structure.

Apparatus of this invention

The machine for cross stretching and long shrinking a web in accordance with the present invention may comprise a feed roll upon which the web is mounted, a "wet-out" device through which the web is passed, means for simultaneously cross stretching and longitudinally shrinking the web, and a batcher or take-up roll for receiving the web after it has been cross stretched and longitudinally shrunk. Guide rolls are provided between the feed roll and the wet-out device and between the cross stretching means and the batcher or take-up roll.

The "wet-out" device comprises a pair of nip rolls and a trough containing liquid in which one of the nip rolls is partially immersed to provide liquid for saturating the web. The web is saturated preferably with from 300 percent to 700 percent of water or an aqueous emulsion of a binder such as polyvinyl acetate.

The means for cross stretching and longitudinally shrinking the web comprises a web deforming zone, carrier means for moving the web into and through said web deforming zone, means constraining successive increments of the web into cylindrical surfaces as said web is moved through said web deforming zone, means progressively increasing the dimension of each cylindrical web increment measured transverse to the direction of web travel, means simultaneously decreasing its dimension measured in the direction of web travel, and means for removing the web from the web deforming zone. In this specification and in the claims, the term "cylindrical" surface means any non-planar surface traced by a straight line, called a generatrix or element, moving parallel to a fixed straight line. The term is not limited to its frequent, but more restricted, sense of a surface generated (traced) by one side of a rectangle rotated around the parallel side as an axis.

The web increment is considered as a relatively short portion of the web having its ends coincident with the opposite edges of the web. In those cases in which the carrier is comprised of a plurality of spaced, individual carrier elements, the dimension of the web increment in the direction of web travel is determined by the spacing of the successive elements of the carrier. The increments each have a dimension in the direction of web travel sufficiently large that successive increments of the web may be engaged with a portion of the surface area of successive carrier elements as the web travels through the web deforming zone.

The web deforming zone includes a laterally extensible carrier adapted to move in an endless closed path, means for holding a web in engagement with the carrier for a predetermined portion of its travel, and means for stretching the carrier and the web transversely of the direction

of web travel throughout said predetermined portion of its travel. The extensible carrier preferably moves at a slightly higher rate than the circumferential speed of the nip rolls of the "wet-out" device mentioned above, to assist in maintaining engagement between the web and the extensible material. The carrier may consist of a flat sheet of extensible material, but preferably comprises a plurality of parallel, spaced, individual extensible carrier elements. Even if the carrier is a flat sheet, of course, it may be considered as a solid extensible sheet made up of a succession of contiguous extensible elements, each having a width of the same order of magnitude as the distance between the individual spaced elements of the preferred type of carrier. Thus, in this specification and claims, the term "succession of extensible elements" includes both a series of spaced elements and a solid extensible sheet.

Specific embodiment shown

The particular embodiment of the machine of this invention shown and described in the specification and drawings employs spaced, individual carrier elements. Opposite ends of each extensible carrier element are secured to a set of cam followers whose movement determines (1) the path through which the carrier element is moved, (2) the amount the element is stretched as it moves through the path, and (3) its spacing from the immediately preceding and following carrier elements as they follow each other around through their common path. The movement of each set of cam followers is jointly controlled by two arrangements of cam slots: (1) a group of radial slots in a rotatably mounted ring gear (which slots, upon rotation of the ring gear, act to drive each set of cam followers continuously in a closed, curved path) and (2) a curved cam slot in each of two spaced cam plates fixedly mounted on opposite sides of the ring gear (which slots determine the shape of the closed path that the carrier elements follow as they are driven by the rotating slotted ring gear).

The cam plates are each provided with identical, continuous, curved cam slots that are entirely within the area defined by the circumference of the slotted ring gears and may define any closed path of travel for the cam followers. Each curved cam slot is eccentrically positioned relative to its associated ring gear and may be of any desired shape, but is preferably ellipsoid. The precise configuration of the cam slot is one of the factors that helps control the amount of cross stretching and long shrinking of the web. The cam plates and associated ring gears at opposite ends of the extensible carrier are angularly disposed, diverging from the feed end of the machine.

At the start of the web deforming zone, where the web is originally moved into engagement with the extensible carrier, the curved cam slots are positioned adjacent the outer ends of the radial cam slots of the ring gears. At the output end of the web deforming zone, where the cross stretched and longitudinally shrunk web is removed from engagement with the extensible carrier, the curved cam slots are positioned near the inner ends of the radial slots.

When the ring gears are rotated, the extensible carrier elements are progressively moved into closer spacing relative to each other, as the curved cam slots cause the cam followers to move from the outer ends of the radial cam slots towards the inner ends thereof. This movement of the cam followers towards the converging inner ends of the radial cam slots causes a contraction of the spacing between adjacent extensible carrier elements as they move towards the output end of the web deforming zone. In the preferred embodiment of this invention, the contraction of the spacing between adjacent elements of the carrier bears a predetermined relationship to the stretching of the carrier elements transverse to the direction of the web travel, so that the area and thus the density of the web material remain approximately constant as the web is simultaneously cross stretched and long shrunk.

Controlled cross stretching and long shrinking

Normally the machine is designed so that the carrier is engaged with the web through approximately 180° of the carrier movement, with the cams arranged to provide 100 percent cross stretch during that engagement. The total longitudinal shrinking during the same movement is preferably 50 percent. To keep the area and weight of each increment of the web approximately constant as it travels through the web deforming zone, the ratio of the respective longitudinal dimensions of the increment when it is engaged by any two carrier elements may be maintained inversely proportional to the ratio of the respective transverse dimensions of the increment when engaged by the same two carrier elements.

The amount of cross stretching and longitudinal shrinking may be varied by removing the web from the carrier before the carrier has rotated 180° or by changing the angularity of the cam plates. As the carrier elements are moved through the web deforming zone under any given set of operating conditions, however, each carrier element is stretched the same predetermined distance and at the same predetermined rate.

The ratio of the long strength to cross strength of the bonded web may be varied within wide limits in accordance with the invention. Depending upon the extent of the stretch of the web, the long tensile strength of the bonded web decreases while the cross tensile strength increases. The stretching can be carried out to such an extent that a starting web which initially has a substantially weaker potential strength in the cross direction than it has in the longitudinal direction is made stronger in the cross direction than in the longitudinal direction, or the stretching can be stopped at any desired point short of this. The invention thus makes possible the production of a web of reoriented fibers having a predetermined potential long-to-cross tensile strength relationship from an initially oriented web which has a relatively weak potential strength in the cross direction. In addition, the invention makes possible a very substantial increase in the potential cross strength with a less than proportional decrease in the potential long strength of the web.

Operation of machine

In the operation of the machine, a fibrous nonwoven web is preferably saturated with water on an aqueous emulsion of a binder such as polyvinyl acetate, and is fed into engagement with the outer surface of an extensible carrier in an area where the width of the carrier is at its minimum. The carrier is preferably comprised of a plurality of spaced, parallel carrier elements that are extensible in the direction transverse to the direction of the web travel.

The web increments are constrained into cylindrical surfaces as the carrier is moved by the rotation of the ring gears, thereby keeping the web increments under tension to help hold the web against the surfaces of the carrier elements. A pressure member, preferably in the form of a brush, engages each outer edge of the web to press it against the surface of the carrier elements and thereby prevent any slippage of the web relative to the carrier elements as the carrier is moved through the web deforming zone.

As the web is cross stretched the water acts as a lubricant to help the fibers move into their reoriented positions, and the cross stretching of the web causes the originally parallelized fibers of the web to gradually move angularly towards right angle relationship relative to their original direction. The stretching operation may be stopped at a point at which the degree of fiber orientation is approximately 50 percent, thus producing a preferred form of the reoriented web in which the potential tensile strengths in the transverse and longitudinal directions are substantially equal.

The machine of the present invention may be used on

strips of web of predetermined length, but preferably the material worked on is in the form of a continuous web which is progressively cross stretched and longitudinally shrunk as it is moved with the carrier elements through that portion of the path of travel defined by the curved cam slots which constitutes the web deforming zone.

The structure, by means of which the above-mentioned and other advantages of the invention are attained, will be described in the following specification, taken in conjunction with the accompanying drawings, showing a preferred illustrative embodiment of the invention in which:

Figure 1 is a three quarters perspective view of the machine, looking from the discharge end toward the feed end, with the drive mechanism omitted for clarity, and with a portion of the near pair of cam plates broken away to show the associated slotted ring gear;

Fig. 2 is a plan view showing the extensible carrier elements in the web deforming zone, with carrier elements stretched and spaced closer to adjacent elements near the discharge end of the machine;

Fig. 3 is a side elevational view of the machine;

Fig. 4 is a plan view of the driving mechanism for rotating the ring gears;

Fig. 5 is a vertical cross sectional view taken substantially along the line 5—5 of Fig. 2, a portion of the near cam plate being broken away to reveal certain details of the construction of the machine;

Fig. 6 is a fragmentary cross sectional view taken substantially along the line 6—6 of Fig. 5;

Fig. 7 is an enlarged fragmentary cross sectional view through one of the cam follower sets showing the relationship between the set of cam followers, the curved cam slots of one of the cam plates, and the associated radial cam slot of the slotted ring gear;

Fig. 8 is a fragmentary cross sectional view showing the web in engagement wtih the extensible carrier elements at the start of the web deforming zone;

Fig. 9 is an enlarged detail perspective view showing a web being held against one of the carrier elements by the pressure member, with a portion of the web broken away to reveal the structure of the extensible carrier element; and

Fig. 10 is a fragmentary cross sectional view, taken along the line parallel to the extensible carrier element of Fig. 9.

A preferred embodiment of the machine, as shown in the drawings, comprises a base, indicated by the reference number 2, having a standard 3 extending upwardly from each side thereof. Each standard is braced by angle members 4. Opposite ends of a stationary shaft 5 are mounted in suitable supports 6 secured to the top of each standard 3. A key 7 prevents rotation of shaft 5.

A stationary cam 8 is rigidly secured adjacent each end of shaft 5. The cam and related structure, hereinafter described, are the same at both sides of the machine, and therefore only the structure at one side will be described in detail, it being understood that the description applies equally well to the corresponding structure at the opposite side of the machine.

The cams 8 are angularly disposed in vertical planes which diverge outwardly from the feed end of the machine at equal angles. The cams may have any desired angularity, depending upon the amount of cross stretching desired and the other factors, such as the maximum radius of the cams, the axial spacing between cams, and the extent of travel of the web through the web deforming zone, which affect the percentage of cross stretching of the web. The divergence of the opposing cam plates, the design of the curved cam slots in the plates, and the spacing between the two pairs of cam plates govern the percentage of cross stretch obtained by use of the machine. In the illustrated embodiment, each of the extensible carrier elements is stretched to double its length from the beginning of the web deforming area to the output end thereof, so that the web will be cross stretched 100 percent of its original width.

Each cam comprises an inner cam plate 9 and an outer cam plate 10, best seen in Fig. 6. Cam plate 9 is secured at its inner edge to an annular plate 11 which encircles shaft 5 and is secured thereto by a screw 12. A sleeve 13, secured against rotation around shaft 5 by key 7, abuts plate 11 and has an integral flange 14 spaced a predetermined distance from plate 11 and extending parallel thereto. Sleeve 13 is provided with a plurality of fins or webs 15 to reinforce flange 14. Cam plate 10 is secured at its inner edge to flange 14. The outer edges of cam plates 9 and 10 have a spacer 16 interposed therebetween to keep the cam plates parallel to each other. The outer edges of cam plates 9 and 10 are secured together by bolts which extend through spacer 16. A bracket 10' secured to one of the angle members 4 is secured to cam plate 10 to help support the outer portion of said cam plate.

Cam plates 9 and 10 are provided with duplicate endless cam slots 17 which provide a closed path of travel for the cam followers hereinafter described. The cam slots may be of any suitable shape, but must be eccentrically arranged relative to the cam plates, as explained in more detail below. For a given plate setting, i.e., angle and spacing, the exact shape of the cam slot controls the amount of cross stretching and longitudinal shrinking of the web, as will be explained more fully hereinafter. The cam slots actually divide each cam plate into two sections which are held together by plurality of brackets 18 spanning the cam slot in cam plate 10, and by the bolts extending through the outer edges of the cam plates and the spacer 16.

A circular plate 19 is rotatably mounted between each pair of cam plates. In the embodiment shown, plate 19 is provided with gear teeth on its periphery to form a ring gear.

The driving mechanism for rotating both ring gears is shown in Figs. 2 and 4. A motor 20 mounted on base 2 has a speed reducer 21 coupled therewith to drive a pulley 22. A belt 23 connects pulley 22 with a pulley 24 mounted on a drive shaft 25. Bevel gears 26, mounted on shaft 25, mesh with bevel gears 27 to rotate gears 28 (Fig. 5), each mounted on a short shaft 29 on which gear 27 is mounted. Gear 28 is meshed with ring gear 19 to rotate it. An annular bushing 30 (Fig. 6), positioned between cam plates 9 and 10, engages the inner edge of ring gear 19. Thrust bearings 31 rotatably mounted in cam plate 9 engage one side of ring gear 19 near its outer edge to help maintain alignment of the ring gear. In Fig. 4, for purposes of clarity, cam plate 9 and outer cam plate 10 of the stationary cams 8 are shown in phantom only, and plates 11 and flanges 14 are omitted altogether.

Each ring gear 19 is provided with a plurality of radial cam slots 32 each of which is long enough to intersect cam slot 17. At the edge of the ring gear closest to the feed mechanism, hereinafter described, the curved cam slot 17 intersects radial cam slots 32 near their outer ends. As the curved cam slot extends towards the opposite edge of the cam plate, the point of intersection with each successive radial cam slot moves closer to the inner, converging ends of the radial slots. Thus, as an inspection of Fig. 5 shows, the distance between adjacent pairs of said points of intersection decreases as the curved cam slot extends towards the output end of the machine. The importance of this arrangement will be hereinafter discussed in connection with the longitudinal shrinking of the web.

A set of cam followers 33 is associated with curved cam slot 17 at each intersection with the radial cam slots 32. Each set of cam followers comprises round cam followers 35 and 36 engaged with curved cam slots 17 in cam plates 9 and 10, respectively, and an intermediate rectangular cam follower 37 engaged with radial cam

slot 32. Pin 34 extends from the inner end of round cam follower 35. Rectangular cam follower 37 is separated from cylindrical cam followers 35 and 36 by plates 38. Round cam followers 35 and 36 may be rigid with pin 34 or may be rotatable. Plates 38 are preferably rectangular, and are sufficiently wide to traverse radial slot 32 to prevent displacement of the cam follower perpendicular to the slotted cam gear, and thus insure proper registration of the respective cam followers with both curved cam slots 17 and radial cam slot 32.

Each pin 34 has a coupling 39 pivotally secured to its inner end to secure opposite ends of carrier elements 40 to the cam followers. Each carrier element 40 comprises a longitudinally extensible coil spring having opposite ends each secured to a coupling 39. As shown in Fig. 6, the pivotal connection of the coupling member 39 with pin 34 permits the coupling member to be aligned with the carrier element in any position of the carrier element as the set of cam followers is moved throughout the path of cam slot 17, and thereby protects the coupling members against excessive strain.

As shown in Fig. 9, the outer surface of each spring or carrier element 40 is knurled or roughened, as indicated at 41, to enhance the frictional contact between the web 42 of fibrous nonwoven material and the carrier elements, and thereby prevent the web from slipping relative to the carrier elements as the carrier elements are moved by the cam followers through the web deforming zone during the rotation of the slotted ring gear.

A more positive frictional contact is provided adjacent the longitudinal edges of the web by a pressure member 43 which is secured to the inner surface of each cam plate 9 by means of a bracket 44 (Fig. 1). Pressure member 43 is a brush-like member comprising a backing 45 of any suitable stiff material, curved to conform to the curvature of the adjacent portion of cam slot 17, and provided with needles 46 adapted to press the edges of the web into firm frictional engagement with the carrier elements. The lower portions of the needles are bent slightly away from direction of travel of web, as indicated at 47, to prevent the needles from tearing or ripping the edges of the web as it is fed into engagement with the carrier elements.

As seen in Figs. 1 and 3, the means for feeding the fibrous nonwoven web to the carrier comprises a feed roll 48, two guide rolls 49 and 50, a "wet-out" device 51, and another guide roll 52. Feed roll 48 is mounted for free rotation in a cradle 53 supported at the top of two standards 54 projecting upwardly from base 2. Guide rolls 49 and 50 are mounted for free rotation in support members 55 built up in any suitable manner from base 2. The "wet-out" device 51 and guide roll 52 are supported by members 56, also projecting upwardly from base 2.

The "wet-out" device comprises upper and lower nip rolls 57 and 58, respectively, and a pan 59 for containing water or an aqueous emulsion of a binder, such as polyvinyl acetate, in which the lower nip roll 58 is partially immersed. Nip roll 58 is driven by a belt 60 through a pulley 60' (Fig. 4) on a shaft 61 mounted in bearings 61'. A belt 62 extending around a pulley 63 mounted on shaft 25 drives shaft 61 through a second pulley 63' mounted on shaft 61.

After the web 42 is fed from the feed roll 48 it passes through the "wet-out" device where it is saturated preferably with from 700 percent to 1500 percent of water, or whatever other liquid is kept in pan 59. The "wet-out" device shown is conventional, and any other suitable means for saturating the web to the desired extent may be used. The saturated web passes under guide roll 52 and then is engaged between one of the carrier elements and the pressure members 43 at the feed end of the web deforming zone of the carrier.

The process of cross stretching and simultaneously longitudinally shrinking the web is preferably continuous, and accordingly, both ring gears 19 are rotated continuously. The rectangular cam follower 37 of each set of cam followers 33 described above moves in its own particular radial cam slot 32, so that as the ring gears make one complete revolution both ends of each carrier element must move through a complete rotation of 360°. Each set of cam followers is also engaged, through round cam followers 36 and 35, with curved cam slots 17, and is therefore restricted in said movement of 360° to the closed path of travel defined by the curved cam slots.

The angularity of cams 8 causes each of the carrier elements to be stretched and contracted during successive half revolutions of the ring gears. The successive carrier elements are contracted as they move from the output end of the carrier to the feed end, at which end they are of minimum length. Each web increment is engaged with an extensible carrier element at or adjacent the point of minimum length of the latter, which is approximately the same length as the initial width of the fibrous, nonwoven web, and its outer edges are positioned between the pressure members 43 and the carrier element. Web increment AB, bounded by planes AA and BB (seen in section in Fig. 8), is shown in the position it occupies just after it has become engaged with a carrier element 40. Web increment BC, also seen in Fig. 8, has moved on into the web deforming zone, having become engaged a moment before with the preceding carrier element 40.

As seen from Fig. 8, each such web increment forms a "cylindrical" surface as defined above. Specifically, in the embodiment shown each surface has a cross-section in the shape of a shallow V with a rounded bottom. The curved portion of this cylindrical surface is that part of the web increment which is in contact with the carrier element; this portion is flanked by two straight sections corresponding to the slanting members of the shallow letter V.

As the rotation of the ring gears moves each carrier element along its closed path of travel, the carrier element, and the increment of the web in engagement therewith, are stretched in the direction normal to the web travel. Successive web increments become engaged with the successive carrier elements as they reach the feed end of the carrier, so that the carrier elements and the web move in a substantially continuous process. Web increments NO, MN, and LM, shown in Fig. 1, are examples of web increments that have become engaged with successive carrier elements 40 and are being moved through the web deforming zone.

The extent of travel of the web with the carrier elements depends largely upon the length of pressure members 43. Preferably, the pressure members 43 extend approximately 180° of the closed path of travel defined by curved cam slots 17. During this movement the stretching of the carrier elements and the web is progressive, and reaches its maximum at the end of 180° of travel. The portion of the closed path of travel of the carrier elements between the feed and output ends of the carrier constitutes the web deforming zone, with the feed end and output end at that zone coinciding with the corresponding ends of the carrier.

As the web is stretched transversely, the shape of curved cam slots 17 forces the cam follower sets to move closer to the inner end of the converging radial cam slots 32 in the ring gears. This movement of the cam followers decreases the longitudinal distance between adjacent carrier elements and the web increments engaged therewith, and thereby shrinks the web longitudinally as it is cross stretched. The angularity of the cams, the axial distance between the cams, and the shape of the cam slot are designed, as explained above, to maintain a constant density or unit web weight throughout the area of the web.

The web may be removed from the carrier at any point beyond the end of the pressure members 43. Pref-

erably, the web is removed from the carrier at a point approximately 180° from the feed end so as to obtain the maximum stretch and the maximum long shrinkage. However, if the angularity of the cams is increased, or the radius of the curved cam slot is increased, the web may be removed from the carrier at a point less than 180° from the feed end and still be stretched to the same extent as in the preferred embodiment.

As shown in Fig. 3, after the web is separated from the carrier it is passed loosely under a guide roll **64**, over a guide roll **65**, and then to a take-up or batcher roll **66**. Guide roll **65** is mounted in standards **67** projecting upwardly from base **2**. A pair of angle irons **68** secured to the rear end of base **2** support batcher roll **66** in open ended notches **69** extending downwardly from the upper end of each angle iron **68**. Another roll **70** is mounted in bearings **70'** provided in angle irons **68** just below the bottom of notches **69**. The notches permit roll **66** to rise as the web winds around it. Roll **70** has the same diameter as roll **65**.

It is desirable to provide slack in the web between the output end of the carrier and the take-up or batcher roll **66** to avoid any draft that would stretch the web longitudinally and tend to nullify the longitudinal shrinkage. The slack in the web is best seen in the vicinity of guide roll **64** in Figs. 3 and 5. The slack is maintained by driving the rolls **65** and **70**, in a manner hereinafter described, at a circumferential rate of speed equal to the linear speed of discharge of the web from the carrier.

The drive mechanism for rolls **65** and **70** is shown in Fig. 2. A pulley **71** mounted on drive shaft **25** transmits the rotation of shaft **25** to another shaft **72** through a belt **73** and a pulley **74** mounted on the latter shaft. Shaft **72** has a gear **75** meshed with another gear **76** mounted on a short shaft **77**. A belt **78** extending around a pulley **79** on shaft **77** and another pulley **80** on the shaft **81** of roll **65** drives the latter roll. The relationships of the gears and pulleys just described make the circumferential speed of roll **65** match the linear speed of the web as it is discharged from the carrier. Moreover, a belt **82** extending around similar pulleys on the shafts of rolls **65** and **70** drives the latter roll at the same angular and circumferential rates as roll **65**. The weight of roll **66** and the web carried thereby resting on roll **70** is sufficient to cause roll **66** to rotate with the rotation of roll **70**, and thereby wrap the cross stretched and long shrunk web around it at the same linear speed at which the web comes off the carrier. Thus, the amount of slack under guide roll **64** remains unchanged.

A housing **83** is provided at one side of the machine to enclose the drive mechanism. A dust guard **84** is provided for the ends of rolls **64** and **65** at the opposite side of the machine.

In the operation of the cross stretching machine described, the movement of a given carrier element from the feed end of the carrier moves the next carrier element into the feed position, and pulls the next web increment into engagement with said second carrier element and the pressure members. As each successive increment of the web engages a carrier element moved to feed position by the movement of the carrier along the closed path defined by the curved cam slot, the web is continuously moved with the carrier elements through a predetermined portion of said path which constitutes the web deforming zone. The pressure members extend around a portion of the path of travel, preferably slightly less than 180°, and the web is separated from the carrier elements at the output end of the web deforming zone, which is preferably adjacent the end of the pressure members.

The carrier elements are of minimum length at the feed end of the carrier and are progressively stretched, in a direction normal to the direction of web travel, at a predetermined rate until they reach their maximum length at or adjacent the output end of the carrier. The knurled surfaces of the carrier elements and the pressure members engaging the outer edges of the web cause the web to be cross stretched along with the carrier elements throughout the web deforming zone.

As the carrier elements are moved from the feed end to the output end of the web deforming zone, the spacing between adjacent carrier elements is progressively decreased to long shrink the web simultaneously with its cross stretching. The curved cam slot is so designed, relative to the angle of divergence of the cams and the axial spacing between the cams, that the desired percentage of cross stretching is obtained, and the longitudinal shrinking of the web is controlled in relation to the cross stretching, so that an approximately constant density or unit web weight is maintained throughout the area of the web.

The travel of the web through the web deforming zone of the carrier, i.e., from the feed end to the output end, effects an important change in the orientation of the individual fibers of the web. At the feed end of the web deforming zone, the degree of fiber orientation in a card web is commonly about 70 percent to 90 percent in the longitudinal direction. As the web moves through the web deforming zone, the orientation of the fibers is changed and the fibers are gradually moved towards transverse orientation. The individual fibers do not move abruptly from one direction to the other, but move gradually in accordance with the extent to which the web has been stretched. The change in direction of most of the fibers is consistent and uniform as the cross stretching proceeds. The frictional resistance between the individual fibers of the saturated web is low enough to permit rearrangement of the fibers in the plane of the web without rupture of the web structure. Since the transverse pull is spread evenly over the whole web, no portion of the web is subjected to strain sufficient to tear it.

Although the cross stretching may be continued until the fibers are generally oriented more in a transverse than in a longitudinal direction, it is preferred to limit the stretching to a point where the degree of fiber orientation is approximately 50 percent, as this arrangement provides maximum potential tensile strength for the web.

While we have described a preferred embodiment of the invention in considerable detail, it will be understood that the description thereof is intended to be illustrative, rather than restrictive, as many details may be modified or changed without departing from the spirit or scope of the appended claims. Accordingly, we do not desire to be restricted to the exact details of construction or method described.

We claim:

1. A method of cross stretching and longitudinally shrinking a nonwoven web comprising a major proportion of oriented textile fibers, individual fibers of said web having frictional resistance therebetween low enough to permit rearrangement of said fibers in the plane of the web without rupture of the web structure, which comprises: saturating said web with water, advancing said saturated web into a web deforming zone with the oriented fibers in the web in the direction of travel, constraining successive increments of the advancing web into cylindrical surfaces, the axes about which said surfaces are traced extending transversely of the direction of travel of the web, moving the web so constrained through the web deforming zone, while progressively increasing to a predetermined figure the dimension of each successive cylindrical web increment measured transverse to the direction of web travel and simultaneously decreasing to a predetermined figure its dimension measured in the direction of web travel, and removing the web from the output end of the web deforming zone when it has been cross stretched and longitudinally shrunk to the predetermined figure.

2. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel, extensible carrier elements, rotatable means for moving said carrier

elements, means for confining said moving carrier elements in a closed path eccentric to the axis of rotation of said rotatable means, a portion of said closed path constituting a web deforming zone having a feed end and an output end, means for moving a nonwoven web into engagement with one of said carrier elements at said feed end, means for progressively stretching said carrier elements in a direction transverse to the direction of web travel as they are moved through said web deforming zone, means for holding said web in engagement with said carrier elements as said carrier elements are moved through said web deforming zone, whereby said web is progressively cross stretched as it is moved through said web deforming zone, means for shrinking said web longitudinally as it is moved through said web deforming zone, and means to remove said web from said carrier at the output end of said web deforming zone.

3. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel coil springs having roughened outer surfaces, rotatable means for moving said coil springs in a closed path eccentric to the axis of rotation of said rotatable means, a portion of said closed path constituting a web deforming zone having a feed end and an output end, means for moving a nonwoven web into engagement with the roughened surface of one of said coil springs at said feed end, means for progressively stretching said springs in a direction transverse to the direction of web travel as they are moved through said web deforming zone, means for holding said web in engagement with said coil springs as said springs are moved through said web deforming zone, whereby said web is progressively cross stretched at it is moved through said web deforming zone, means for shrinking said web longitudinally as it is moved through said web deforming zone, and means to remove said web from said carrier at the output end of said web deforming zone.

4. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel coil springs having roughened outer surfaces, rotatable means for moving said coil springs in a closed path eccentric to the axis of rotation of said rotatable means, a portion of said closed path constituting a web deforming zone having a feed end and an output end, means for moving a nonwoven web into engagement with one of said coil springs at said feed end, means for stretching each of said coil springs in a direction transverse to the direction of web travel as it is moved through said web deforming zone, pressure means to hold said web in engagement with the roughened surface of said coil springs as said springs are moved through said web deforming zone, whereby said web is progressively cross stretched as it is moved through said web deforming zone, means for shrinking said web longitudinally as it is moved through said web deforming zone, and means to remove said web from said carrier at the output end of said web deforming zone.

5. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel carrier elements, a cam positioned on each side of said carrier, said cams having duplicate cam slots, a plurality of cam followers in each of said cam slots, rotatable means for moving said carrier elements in a closed path defined by said cam slots, said cam slots being eccentric to the axis of rotation of said rotatable means, a portion of said closed path constituting a web deforming zone having a feed end and an output end, said cams diverging from each other from said feed end to said output end, means for moving a nonwoven web into engagement with one of said carrier elements at said feed end, each of said carrier elements having its opposits ends secured to one of said cam followers, whereby said carrier elements are stretched in a direction transverse to the direction of web travel as they are moved through said web deforming zone, means to hold said web in engagement with said carrier elements as said carrier elements are moved through said web deforming zone, whereby said web is progressively cross stretched with said carrier elements as it is moved through said web deforming zone, means for shrinking said web longitudinally as it is moved through said web deforming zone, and means to remove said web from said carrier at the output end of said web deforming zone.

6. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel carrier elements, rotatable means for moving said carrier elements in a closed path eccentric to the axis of rotation of said rotatable means, a portion of said closed path constituting a web deforming zone having a feed end and an output end, means for moving a nonwoven web into engagement with one of said carrier elements at said feed end, means for stretching said carrier elements in a direction transverse to the direction of web travel as they are moved through said web deforming zone, the eccentricity of said closed path causing said carrier elements to move into closer spacing as they are moved through said web deforming zone, means to hold said web in engagement with said carrier elements as said carrier elements are moved through said web deforming zone, whereby said web is progressively cross stretched and longitudinally shrunk as it is moved through said web deforming zone, and means to remove said web from said carrier at the output end of said web deforming zone.

7. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel, extensible carrier elements, a cam positioned on each side of said carrier, said cams having duplicate cam slots, a plurality of cam followers in each of said cam slots, rotatable means for moving said carrier elements in a closed path defined by said cam slots, said cam slots being eccentric to the axis of rotation of said rotatable means, a portion of said closed path constituting a web deforming zone having a feed end and an output end, said cams diverging from each other from said feed end to said output end, means for moving a nonwoven web into engagement with one of said carrier elements at said feed end, each of said carrier elements having its opposite ends secured to one of said cam followers, whereby said carrier elements are stretched in a direction transverse to the direction of web travel as they are moved through said web deforming zone, the eccentricity of said closed path causing said carrier elements to move into closer spacing as they are moved through said web deforming zone, means to hold said web in engagement with said carrier elements as said carrier elements are moved through said web deforming zone, whereby said web is progressively cross stretched and longitudinally shrunk as it is moved through said web deforming zone, and means to remove said web from said carrier at the output end of said web deforming zone.

8. An apparatus for cross stretching a nonwoven web comprising a carrier, means for moving said carrier in a closed path, means for holding a web in engagement with said carrier during movement of said carrier through a predetermined portion of said closed path, said carrier comprising a series of spaced, parallel carrier elements each extensible in a direction transverse to the direction of web travel, means for progressively stretching each of said carrier elements in a direction transverse to the direction of web travel as said carrier is moved through said predetermined portion of said closed path, means for simultaneously moving said carrier elements into closer spacing, and means to remove said web from said carrier in the area of closest spacing of said carrier elements.

9. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel, extensible carrier elements, said carrier having a web deforming zone having a feed end and an output end, means to move said carrier elements through said web deforming zone, means to move a web into engagement with said

carrier elements, means to stretch each of said carrier elements in a direction transverse to the direction of travel of said carrier elements as they are moved between the feed end of said web deforming zone and the output end thereof, means to hold said web in engagement with said carrier elements during movement of said carrier elements through said web deforming zone, and means to move said carrier elements into closer spacing to shrink said web longitudinally as it travels through said web deforming zone.

10. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel, extensible carrier elements, a cam positioned adjacent opposite sides of said carrier, each of said cams having an identical endless cam slot, a portion of said cam slots defining a web deforming zone having a feed end and an output end, a plurality of cam followers in each of said slots, one of said cam followers being secured to one end of each of said carrier elements, means to move a web into engagement with said carrier elements, means to move said cam followers along said cam slots, means to move said carrier elements into closer spacing as their associated cam followers are moved through the portion of the cam slots defining said web deforming zone, means for progressively stretching said carrier elements as they are moved through said web deforming zone, means to hold said web in engagement with said carrier elements during movement of said carrier elements through said web deforming zone, whereby said web is simultaneously cross stretched and longitudinally shrunk, and means for removing said web from said carrier elements at the output end of said web deforming zone.

11. An apparatus for simultaneously cross stretching and longitudinally shrinking a nonwoven web comprising a pair of cams in diverging angular relationship, each of said cams having an endless curved cam slot, a plurality of cam followers in each of said curved cam slots, a rotatable plate juxtaposed against each of said cams, means for rotating said plates, said plates being engaged with said cam followers to move said cam followers along said cam slots as said plates are rotated, an endless series of carrier elements, each of said carrier elements having its opposite ends each secured to one of said cam followers, means for moving successive web increments into engagement with successive carrier elements as said carrier elements are moved by said cam followers, means for stretching each of said carrier elements in a direction transverse to the direction of web travel as said carrier elements are moved through a predetermined portion of their travel, said predetermined portion of the travel of said carrier elements comprising a web deforming zone having a feed end and an output end, means for maintaining said web increments in engagement with said carrier elements as said carrier elements are moved through said web deforming zone, whereby said successive web increments are stretched transversely of the direction of web travel as they are moved through said web deforming zone in engagement with said carrier elements, means for moving said carrier elements into closer spacing as they approach the output end of said web deforming zone to shrink said web longitudinally during the transverse stretching thereof, and means to remove said web increments from said carrier elements at said output end of said web deforming zone.

12. An apparatus for simultaneously cross stretching and longitudinally shrinking a nonwoven web comprising a pair of cams in diverging angular relationship, each of said cams having an endless curved sam slot, a plurality of cam followers in each of said curved cam slots, a rotatable plate juxtaposed against each of said cams, means for rotating said plates, said plates being engaged with said cam followers to move said cam followers along said cam slots as said plates are rotated, an endless series of carrier elements, each of said carrier elements having its opposite ends each secured to one of said cam followers, means for moving successive web increments into engagement with successive carrier elements as said carrier elements are moved by said cam followers, means for stretching each of said carrier elements in a direction transverse to the direction of web travel as said carrier elements are moved through a predetermined portion of their travel, said predetermined portion of the travel of said carrier elements comprising a web deforming zone having a feed end and an output end, means for maintaining said web increments in engagement with said carrier elements during movement of said carrier elements through said web deforming zone, whereby said successive web increments are stretched transversely of the direction of web travel as they are moved through said web deforming zone in engagement with said carrier elements, means for moving said carrier elements into closer spacing as they approach the output end of said web deforming zone, whereby said web increments are longitudinally shrunk simultaneously with said transverse stretching thereof, and means to remove said web increments from said carrier elements at the output end of said web deforming zone.

13. An apparatus for simultaneously cross stretching and longitudinally shrinking a nonwoven web comprising an enless series of extensible carrier elements movable in a closed path, means for moving said carrier elements through said closed path, means for moving successive web increments into engagement with successive carrier elements during movement of said carrier elements, means for stretching each of said carrier elements in a direction transverse to the direction of web travel as said carrier elements are moved through a predetermined portion of said closed path comprising a web deforming zone having a feed end and an output end, means for maintaining said web increments in engagement with said carrier elements during movement of said carrier elements through said web deforming zone, whereby said successive web increments are stretched transversely of the direction of web travel as they are moved through said web deforming zone in engagement with said carrier elements, means for long shrinking said web increments as they are moved with said carrier elements through said web deforming zone, and means to remove said web increments from said carrier elements at said output end of said web deforming zone.

14. A cross stretching apparatus comprising a series of spaced, parallel extensible carrier elements mounted for movement along a closed path, means for moving successive carrier elements along said closed path, means operable to stretch said carrier elements as they are moved from an initial position in said closed path to a second position in said path removed from said initial position by approximately 180°, said carrier elements being of minimum length at said initial position and of maximum length at said second position, the portion of said closed path between said initial and said second position constituting a web deforming zone, means for moving an increment of a nonwoven web into engagement with a carrier element at said initial position, means for holding said web increment in engagement with said carrier element as said carrier element is moved through said web deforming zone, whereby said web increment is cross stretched progressively with said carrier element, means for moving said carrier elements into closer spacing as they approach the output end of said web deforming zone to shrink said web increment longitudinally during the cross stretching thereof, and means for removing said cross stretched and longitudinally shrunk web increment from said carrier element at said second position in said closed path.

15. A cross stretching apparatus comprising a series of spaced, parallel extensible carrier elements mounted for movement along a closed path, means for moving successive carrier elements along said closed path in prede-

termined relationship, means operable to stretch said carrier elements as they are moved from an initial position in said closed path to a second position in said closed path removed from said initial position by approximately 180°, said carrier elements being of minimum length at said initial position and of maximum length at said second position, said carrier elements being spaced apart a greater distance adjacent said initial position than adjacent said second position, the portion of said closed path between said initial position and said second position constituting a web deforming zone, means for moving successive increments of a nonwoven web into engagement with successive carrier elements as said successive carrier elements are moved into said initial position, means for holding each of said web increments in engagement with its carrier element as said carrier elements are moved through said web deforming zone, whereby each of said web increments is progressively cross stretched and longitudinally shrunk simultaneously in said web deforming zone, and means for removing said successive web increments from said carrier elements at said second position.

16. A cross stretching machine comprising a plurality of extensible carrier elements, means for holding a fibrous nonwoven web in engagement with said carrier elements, a cam positioned adjacent each end of said carrier elements, said cams being fixed in diverging relationship, a rotatable ring gear juxtaposed against each of said cams, each of said cams having an endless curved cam slot eccentric to said juxtaposed ring gear, each of said ring gears having a plurality of radial cam slots, each of said radial slots intersecting the curved cam slot of the adjacent cam, a set of cam followers secured to one end of each carrier element, said set comprising a first cam follower engaged with each of said radial cam slots and a second cam follower associated with the first cam follower and engaged with the curved cam slot intersected by said radial slot, said curved cam slots being shaped to force said carrier elements into closer spacing with adjacent carrier elements as they approach the output end of said web deforming zone, means to rotate said ring gears at the same rate, whereby said carrier elements, with said web in engagement therewith, are moved in a closed path defined by said curved cam slots, and means for removing said web from said carrier elements at a predetermined point in said closed path of travel.

17. A cross stretching apparatus comprising a pair of vertically disposed cams, a rotatable ring gear juxtaposed against each of said cams, means for rotating said ring gears at the same rate, each of said cams having an identical endless curved cam slot, a plurality of cam followers mounted in spaced relationship in each of said curved cam slots, said cam followers being connected to said ring gears, whereby said cam followers are movable in said cam slots by rotation of said ring gears, a series of spaced, parallel coiled springs, each of said springs having its opposite ends secured to a cam follower in each of said curved cam slots, whereby said springs are moved through a closed path defined by said cam slots as said ring gears are rotated, a portion of said closed path constituting a web deforming zone having a feed end and an output end, said cams diverging from said feed end to the output end of said web deforming zone, whereby said springs are stretched as they are moved through said web deforming zone, means for engaging a nonwoven web with the surface of a spring positioned at said feed end, a pressure member mounted on each of said cams adjacent said cam slots, said pressure member comprising a backing and a plurality of closely spaced needles engageable with said web to hold it in against the surface of said spring, said pressure members being shaped to conform to the curvature of said cam slots and extending from said feed end to said output end to permit removal of said web from said spring at said output end, and said curved cam slots being shaped to cause said springs to move into closer spacing as they are moved through said web deforming zone, whereby said web is simultaneously cross stretched and long shrunk as it is moved through said web deforming zone.

18. A cross stretching apparatus comprising a pair of vertically disposed cams, a rotatable ring gear juxtaposed against each of said cams, means for rotating said ring gears at the same rate, each of said ring gears having a plurality of radial slots extending approximately from its center to its outer edge, each of said cams having identical endless curved cam slots, each of said radial slots intersecting the curved cam slot of the adjacent cam, a plurality of sets of cam followers mounted in said radial and curved cam slots, each of said sets comprising a first cam follower engaged with one of said radial slots and a second cam follower associated with the first cam follower and engaged with the curved cam slot at its intersection with said one radial slot, whereby said cam followers are movable in said cam slots by rotation of said ring gears, a series of spaced, parallel coiled springs, each of said springs having its opposite ends secured to a cam follower in each of said cam slots, whereby said springs are moved through a closed path defined by said cam slots as said ring gears are rotated, a portion of said closed path constituting a web deforming zone having a feed end and an output end, said cams diverging from said feed end to the output end of said web deforming zone, whereby said springs are stretched as they are moved through said web deforming zone, means for engaging a nonwoven web with the surface of a spring positioned at said feed end, a presusre member mounted on each of said cams adjacent said cam slots, said pressure member comprising a backing and a plurality of closely spaced needles, the lower portion of each of said needles being bent slightly away from the direction of web travel and engageable with said web to hold it in against the surface of said spring, said pressure members being shaped to conform to the curvature of said cam slots and extending from said feed end to said output end to permit removal of said web from said springs at said output end, and said curved cam slots being shaped to cause said springs to move into closer spacing as they are moved through said web deforming zone, whereby said web is simultaneously cross stretched and long shrunk as it is moved through said web deforming zone.

19. A cross stretching apparatus comprising an extensible carrier, rotatable means for moving said carrier, means for confining said moving carrier in a closed path eccentric to the axis of rotation of said rotatable means, a portion of said closed path constituting a web deforming zone having a feed end and an output end, means for moving a nonwoven web into engagement with said carrier at said feed end, means for progressively stretching said carrier in a direction transverse to the direction of web travel as the carrier is moved through said web deforming zone, means for holding said web in engagement with said carrier as the latter is moved through said web deforming zone, whereby said web is progressively cross stretched as it is moved through said web deforming zone, means for shrinking said web longitudinally as it is moved through said web deforming zone, and means to remove said web from said carrier at the output end of said web deforming zone.

20. A cross stretching apparatus comprising a carrier consisting of a succession of extensible elements, a cam positioned on each side of said carrier, said cams having duplicate cam slots defining a closed curved path, a plurality of cam followers in each of said cam slots, rotatable means for moving said succession of carrier elements in said closed cam path defined by said cam slots, said cam slots being eccentric to the axis of rotation of said rotatable means, a portion of said closed path constituting a web deforming zone having a feed end and an output end, said cams diverging from each other from said feed end to said output end, means for moving a nonwoven web into engagement with said carrier at said feed end,

each of the elements comprising said carrier having its opposite ends secured to one of said cam followers whereby said carrier is stretched in a direction transverse to the direction of web travel as the carrier is moved through said web deforming zone, means to hold said web in engagement with said carrier as the latter is moved through said web deforming zone, whereby said web is progressively cross stretched with said carrier as it is moved through said web deforming zone, means for shrinking said web longitudinally as it is moved through said web deforming zone, and means to remove said web from said carrier at the output end of said web deforming zone.

21. An apparatus for simultaneously cross stretching and longitudinally shrinking a nonwoven web comprising an extensible carrier, rotatable means for moving said carrier, means for confining said moving carrier in a closed path, a portion of said closed path constituting a web deforming zone having a feed end and an output end, means for moving at least a portion of each of successive increments of a nonwoven web into engagement with said carrier at said feed end, said moving carrier constraining into cylindrical surfaces said successive increments of the advancing web as they become engaged with said carrier, the axes of said cylindrical surfaces extending transversely of the direction of travel of the web, means for progressively stretching said carrier in a direction transverse to the direction of web travel as the carrier is moved through said web deforming zone, means for simultaneously progressively decreasing the dimension of each successive cylindrical web increment measured in the direction of web travel, whereby said web is progressively cross stretched and long shrunk as it is moved through said web deforming zone, and means for removing said web from said carrier at the output end of said web deforming zone.

22. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel, extensible carrier elements, said carrier having a web deforming zone having a feed end and an output end, means to move said carrier elements through said web deforming zone, means to move a web into engagement with said carrier elements, means to hold said web in engagement with said carrier elements during movement of said carrier elements through said web deforming zone, means to stretch each of said carrier elements at a predetermined rate in a direction transverse to the direction of travel of said carrier elements as they are moved between the feed end of said web deforming zone and the output end thereof, and means to move each of said carrier elements closer to the immediately preceding carrier element at a predetermined rate as the elements pass through said web deforming zone so as to shrink said web longitudinally as it travels through said zone.

23. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel, extensible carrier elements, a cam positioned on each side of said carrier, said cams having duplicate cam slots, a plurality of cam followers in each of said cam slots, rotatable means for moving said carrier elements in a closed path defined by said cam slots, said cam slots being eccentric to the axis of rotation of said rotatable means, a portion of said closed path constituting a web deforming zone having a feed end and an output end, said cams diverging from each other from said feed end to said output end, means for moving a nonwoven web into engagement with one of said carrier elements at said feed end, each of said carrier elements having its opposite ends secured to one of said cam followers, whereby said carrier elements are stretched in a direction transverse to the direction of web travel at a predetermined rate as they are moved through said web deforming zone, the eccentricity of said closed path causing said carrier elements to move into closer spacing at a predetermined rate as they are moved through said web deforming zone, means to hold said web in engagement with said carrier elements as said carrier elements are moved through said web deforming zone, whereby said web is progressively cross stretched and longitudinally shrunk as it is moved through said web deforming zone, and means to remove said web from said carrier at the output end of said web deforming zone.

24. A method of cross stretching and longitudinally shrinking a nonwoven web comprising a major proportion of oriented textile fibers, individual fibers of said web having frictional resistance therebetween low enough to permit rearrangement of said fibers in the plane of the web without rupture of the web structure, which comprises: saturating said web with water, advancing said saturated web into a web deforming zone with the oriented fibers in the web in the direction of travel, constraining successive increments of the advancing web into cylindrical surfaces, the axes about which said surfaces are traced extending transversely of the direction of travel of the web, moving the web so constrained through the web deforming zone, while progressively increasing to a predetermined figure and at a predetermined rate the dimension of each successive cylindrical web increment measured transverse to the direction of web travel and simultaneously decreasing to a predetermined figure and at a predetermined rate its dimension measured in the direction of web travel, and removing the web from the output end of the web deforming zone when it has been cross stretched and longitudinally shrunk to the predetermined figure.

25. A cross stretching apparatus comprising a carrier consisting of a plurality of spaced, parallel, extensible carrier elements, a cam positioned on each side of said carrier, said cams having duplicate cam slots, a plurality of cam followers in each of said cam slots, rotatable means for moving said carrier elements in a closed curved path defined by said cam slots, said cam slots being eccentric to the axis of rotation of said rotatable means, a portion of said closed path constituting a web deforming zone having a feed end and an output end, said cams diverging from each other from said feed end to said output end, means for moving a nonwoven web into engagement with one of said carrier elements at said feed end, each of said carrier elements having its opposite ends secured to one of said cam followers, whereby said carrier elements are stretched in a direction transverse to the direction of web travel as they are moved through said web deforming zone, means to hold said web in engagement with said carrier elements as said carrier elements are moved through said web deforming zone, whereby said web is progressively cross stretched with said carrier elements as it is moved through said web deforming zone, means for shrinking said web longitudinally as it is moved through said web deforming zone, and means to remove said web from said carrier at the output end of said web deforming zone.

References Cited in the file of this patent

UNITED STATES PATENTS

2,171,551	Hannig	Sept. 5, 1939
2,591,861	Pannaci	Apr. 8, 1952
2,702,406	Reed	Feb. 22, 1955
2,715,761	Dougherty	Aug. 23, 1955

FOREIGN PATENTS

401,617	Great Britain	Nov. 16, 1933