United States Patent

[11] 3,630,837

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Greenwich, Conn.
[21] Appl. No. 799,864
[22] Filed Feb. 17, 1969
[45] Patented Dec. 28, 1971
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[54] **COMPACTING APPARATUS FOR FIBROUS WEBS**
9 Claims, 15 Drawing Figs.

[52] **U.S. Cl.** **162/361,** 26/18.6, 162/205
[51] **Int. Cl.** **Z10h 5/00**
[50] **Field of Search** 162/117, 205, 358, 361; 26/18.6

[56] **References Cited**

UNITED STATES PATENTS

3,471,363 10/1969 Schmidt .... 162/205 X

FOREIGN PATENTS

903,508 8/1962 Great Britain 162/205

Primary Examiner—S. Leon Bashore
Assistant Examiner—Thomas G. Scavone
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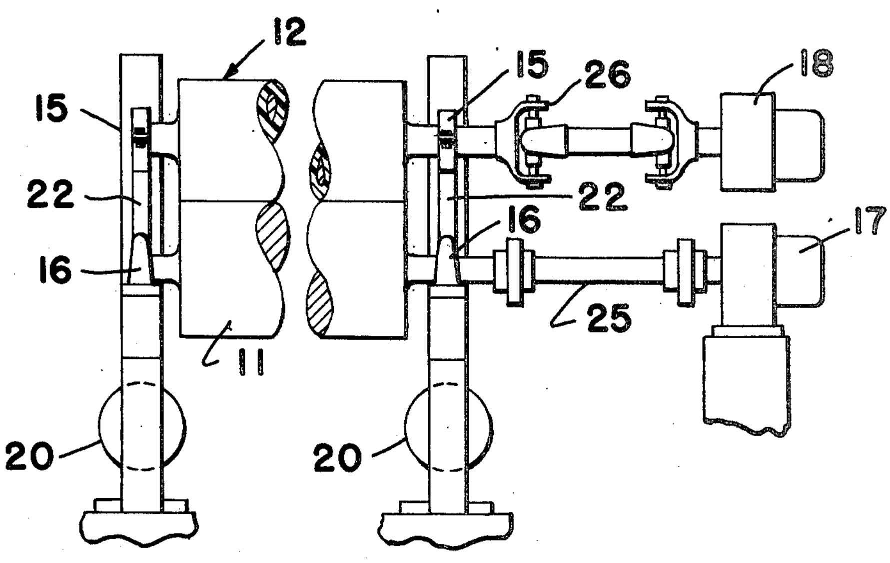
ABSTRACT: Compacting apparatus for producing paper having isotropic extensibility including an elastomeric element having structural components orientated at an oblique angle not less than 15° but not more than 75° with respect to at least one of the principal axes of the pressure nip of the apparatus. The components may be, for example, relatively inelastic cords, coarse hair fibers, or channels.



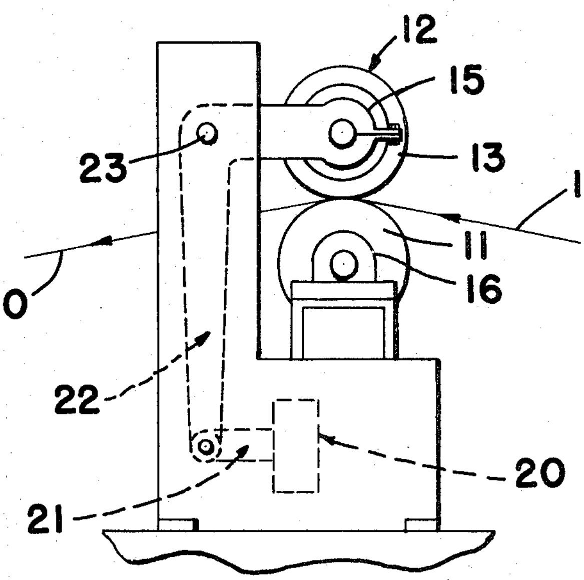


FIG. 1

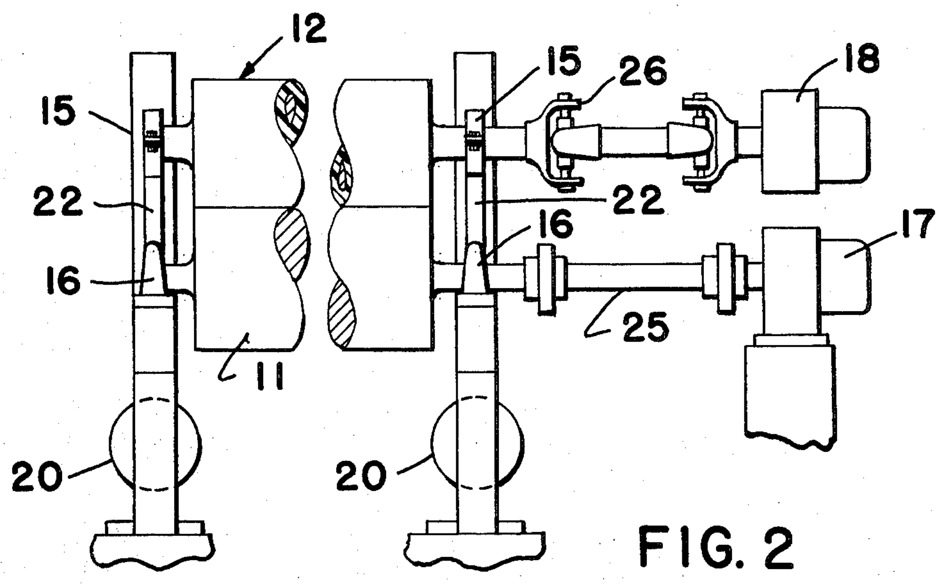


FIG. 2

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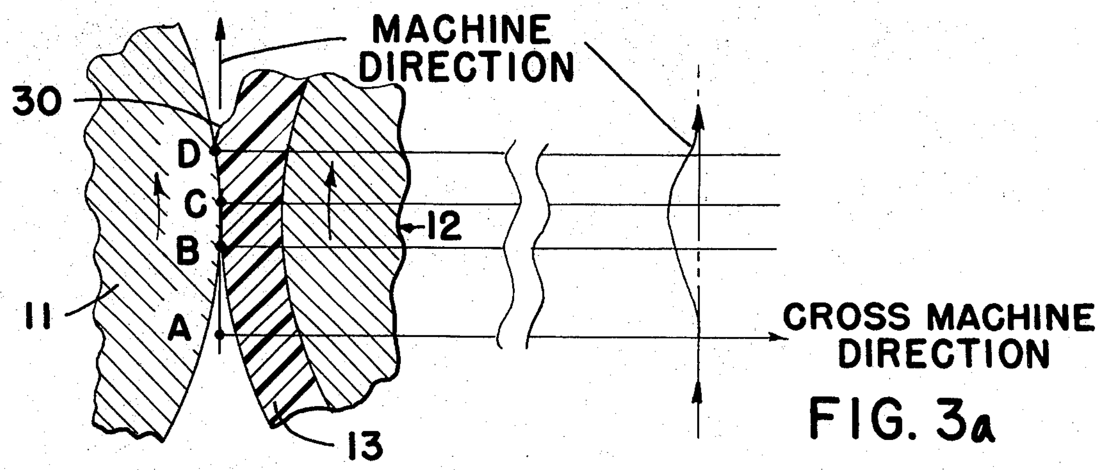

FIG. 3a

FIG. 3

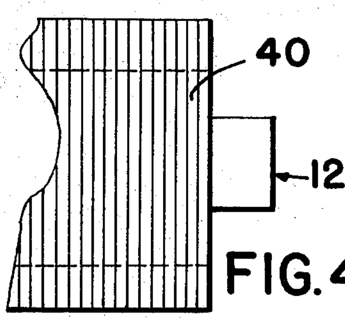

FIG. 4

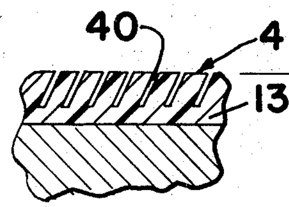

FIG. 4a

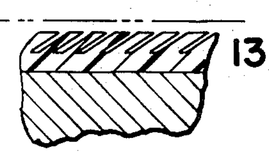

FIG. 4b

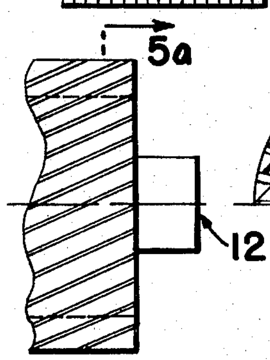

FIG. 5

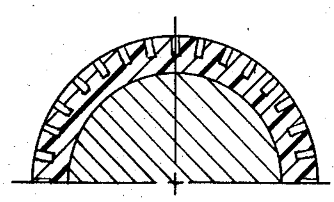

FIG. 5a

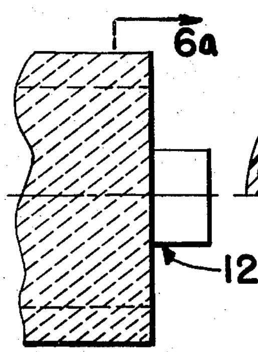

FIG. 6

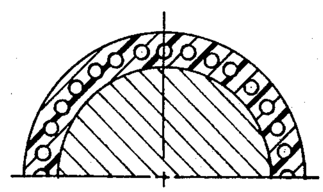

FIG. 6a

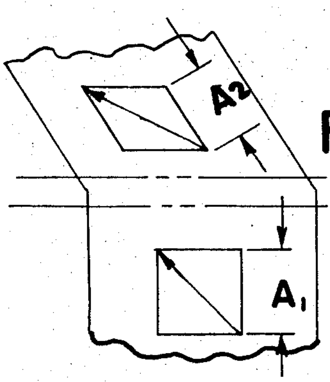

FIG. 7

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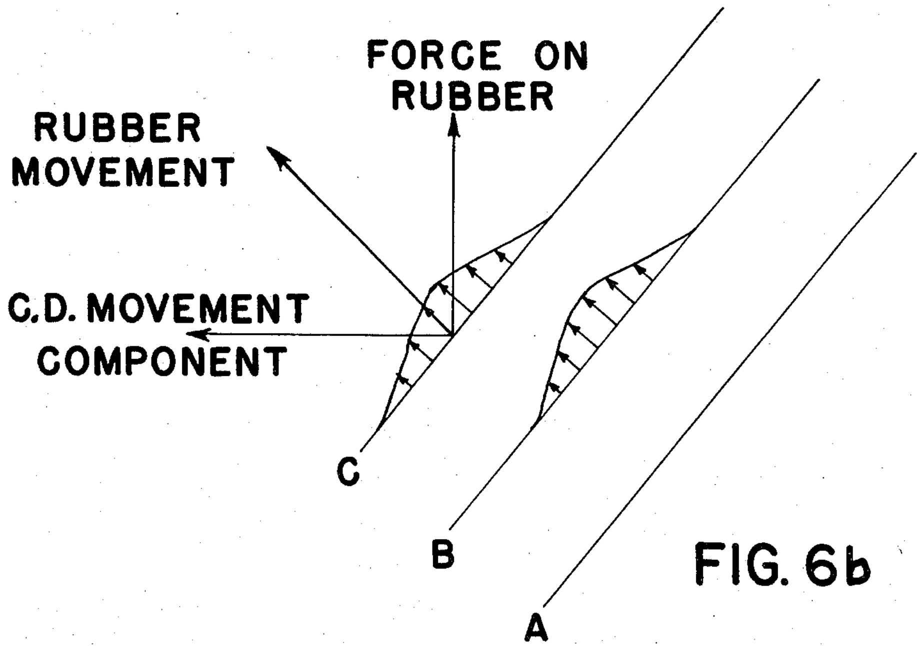

FIG. 6b

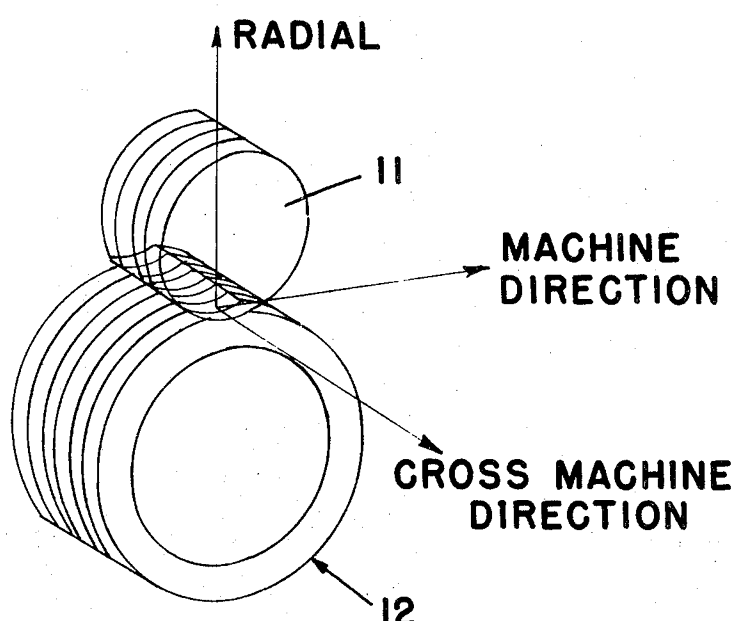

FIG. 7a

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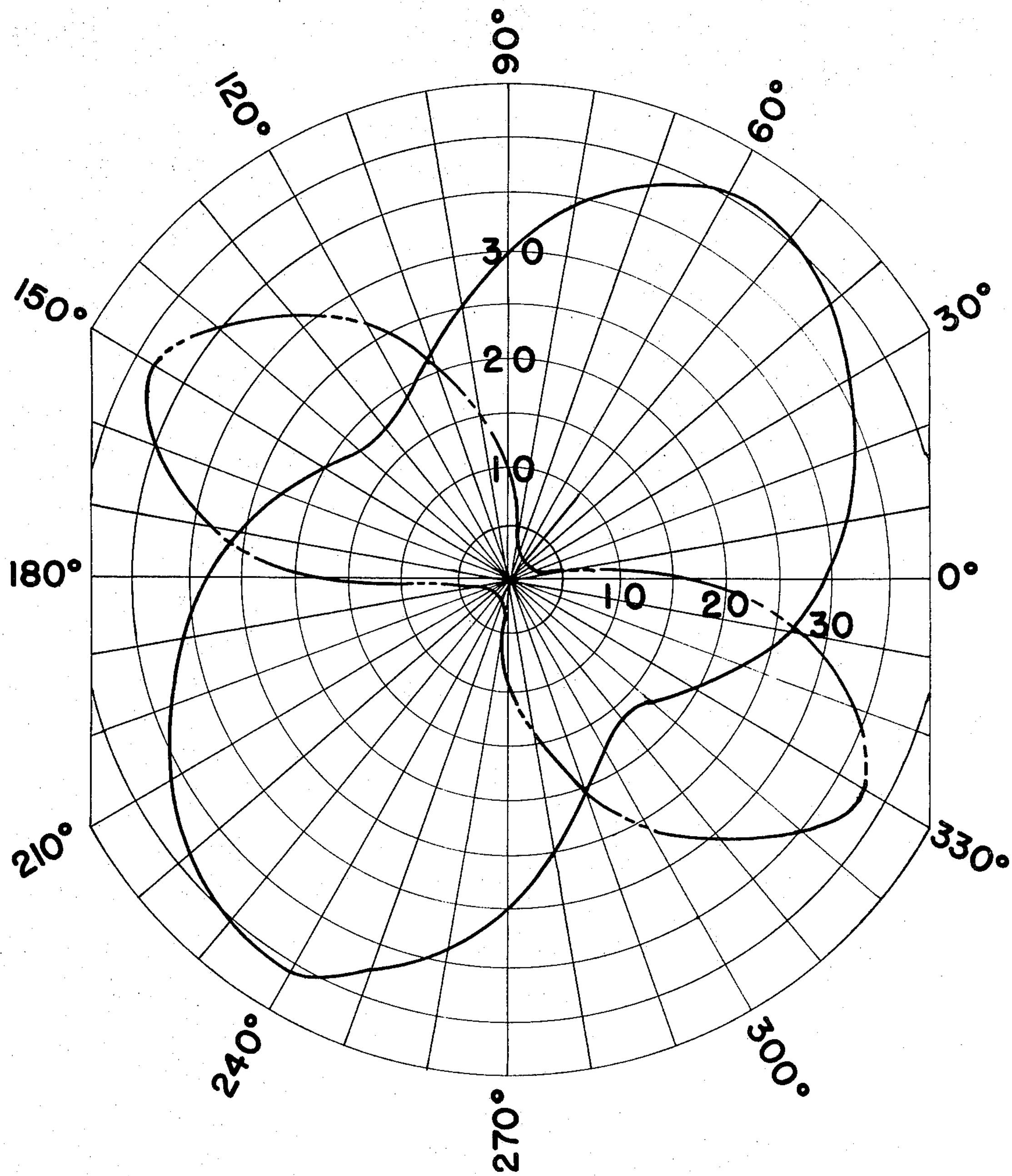

FIG. 8

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COMPACTING APPARATUS FOR FIBROUS WEBS

BACKGROUND OF THE INVENTION

The field of the present invention is the mechanical compaction of fibrous webs such as paper and the like. A major reason for compacting such webs is to impart to them a toughness and stretchability greater than that of a similar web that has not been compacted. It is known in the prior art to compact webs between a hard surface and a relatively elastic surface. In this regard reference is made to U.S. Pat. No. 2,624,245 to S. L. Cluett. This patent describes a method and apparatus for mechanically compacting paper by compressing a paper web longitudinally and parallel to its surfaces. The fibers of the web while in a partially dry condition are continuously pushed and crowded together in the space between the faces of the web as laid as the web moves in a lengthwise direction. The Cluett patent describes only compressing the paper in the machine or "running" direction of the web.

It was soon appreciated that a paper which exhibits stretchability in all directions would be a desirable improvement over paper which can stretch in only one direction since the majority of load conditions to which stretchable paper may be subjected cause forces to act in all directions on the paper. Because paper, for example in a sack, will tend to fail first in the direction of least stretch in the paper, the increased one-way stretch provided by the S. L. Cluett invention is not fully utilized. For maximum effectiveness, the extensibility should be present in more than one direction—and ideally in all directions.

The problem of producing extensibility in other than the machine direction found a solution in the invention of Fred H. Freuler set out in U.S. Pat. No. 3,122,469. The Freuler patent describes machinery which may be used to produce paper having extensibility in mutually crossing directions. To accomplish this multidirectional extensibility, a pair of rigid rods are used in conjunction with an endless elastomeric surfaced blanket. The rods are disposed parallel to each other but obliquely in relation to the direction of web and blanket travel. The particular direction of shrinking is determined by the angular adjustment of the rods in relation to the direction of travel of the blanket and the web. This concept teaches the desirability of producing oblique extensibility; however, the apparatus, which has been termed an ABC (angle bar compactor) unit because of its obliquely disposed rods, presents some problems such as high initial cost, high maintenance and extensive floor space requirements.

SUMMARY OF THE INVENTION

The present invention provides a new means for producing the isotropic web described in U.S. Pat. No. 3,122,469 while overcoming the problems of cost and space encountered with the ABC unit.

In the instant invention, the oblique shrinking of the web takes place due to the unique construction of the elastomeric surfaced roller or the elastomeric blanket and is not dependent upon the disposition of the nip members in relation to the web.

The present invention achieves extensibility of the web in other than the machine direction by making use of structural components in the elastomeric element which are orientated at an oblique angle to at least one of the three principal axes of the compacting nip. Examples of such components are inelastic cords embedded just below the surface of the elastomeric element, coarse hair fibers embedded in the body of the elastic material or channels cut into the surface of the elastomeric element.

As disclosed herein, isotropic extensible webs may be produced which exhibit in more than one direction increased toughness and resistance to impact loading, and to rupture due to localized strain, on both double roll and blanket compacting units and without recourse to obliquely disposed nip rods so that the instant invention is of significant benefit to the papermaking and other industries.

Therefore, it is an object of the invention to provide an improved method and apparatus for producing isotropic extensible webs.

THE DRAWINGS

FIG. **1** is a view of a mechanical compaction apparatus showing the location of the various apparatus components;

FIG. **2** is a similar view showing the drive means;

FIG. **3** is a detail of a compaction nip according to the instant invention including a graph **3*a*** showing the flow of rubber in the nip due to the indentation of the hard roll against the rubber;

FIGS. **4, 5**, and **6** are detailed drawings of three methods of construction of the rubber roller to practice the instant invention;

FIGS. **4*a*, 4*b*, 5*a*** and **6*a*** are further details of the constructions shown in FIGS. **4, 5**, and **6**;

FIG. **6*b*** is a diagram showing distortion of the restraining components in the nip;

FIG. **7** is a schematic drawing showing the direction of travel of the web through the nip described herein;

FIG. **7*a*** shows the location of the principal axes of the nip; and

FIG. **8** is a chart showing stretch characteristics of a web illustrating the effects of processing according to this invention.

The drawings should be understood to be more or less of a diagrammatic character for purposes of illustration. Like reference characters identify like elements in the several views.

DESCRIPTION OF PREFERRED EMBODIMENTS

The invention will be described with respect to an apparatus using two engaging rollers, one having a hard surface and the other having a thick elastomeric covering. However, it will be appreciated that the principles described hereinafter may be applied to other apparatus configurations. Additionally, the invention will be described with respect to paper, but it should be realized that the method and apparatus of the invention may be applied to the making of a wide variety of fibrous webs for example, nonwovens and tissues.

FIG. **1** shows a double-roll compactor arrangement. The paper web **10** passes between cylindrical rollers **11** and **12** which form a pressure nip. Roller **11** is typically a hard surfaced, slippery roller. Its surface may be for example, steel or chromium. This surface may be flat, or it may, for example, have nodules or shallow grooves in order to aid in the slippage of the paper over the roll surface.

Roll **12** is typically a metal drum covered with a thick rubber band **13**, the nature of which will be discussed at greater length hereinafter. There must be a speed differential between the peripheral advance of the two rollers. This can be achieved by driving the two rollers off a positive drive arrangement such as is shown in FIG. **2**.

Roller **11** may be heated if desired.

Both rollers are journaled on bearings **15** and **16**. The hard roller **11** is driven by motor **17**. The relatively soft surfaced roller **12** (hereinafter the soft roller) is driven by motor **18**. Simultaneously, the soft roller is urged against the surface of the hard roller by the action of diaphragms **20** which act through linkages **21** and pivot arms **22**. The pivot arms carry the bearings **15** in which the soft roller is journaled. Horizontal movement of the diaphragms is translated into downward motion of the roller as the arms swing about pivot **23**. This mechanism allows the compacting nip pressure to be adjusted for different process conditions.

The rollers of the double-roll compactor lie substantially at right angles to the web at the inlet side of the nip. In practice there may be some slight misalignment, but that is generally less than 5° with respect to the line normal to the web edges. In discussing double-roll compactors, the axes of the rollers are generally considered to lie at right angles to the web edges so that the cross-machine direction can be taken as the shortest crosswise dimension of the web.

FIG. 2 shows the coupling mechanisms used to drive rollers 11 and 12. The hard roller 11 is driven through a short connecting shaft 25 by a variable speed motor 17. The soft roller 12 is driven through a connecting shaft utilizing a universal coupling 26 to allow for movement of the roller as the nip pressure is varied. Any suitable means of differentially driving the two rollers may be used instead of the arrangement discussed above. For example, an electric generator brake could be connected to the soft roller 12 and the generated electric power recycled to conserve energy.

FIG. 3 is a fragmentary cross section of the nip taken normal to the axis of the rollers. The zone between the letters B and D is the actual zone in which the rubber surface is indented by the surface of the hard roller. The distortion of the rubber surface in radial and machine directions is asymetric because of the difference in surface speeds, resulting in a hump 30 at the outlet side of the pressure nip. In addition to this machine direction distortion, the apparatus of the instant invention is associated with a flow of rubber in the cross-machine direction. FIG. 3*a* is a graph showing the typical cross-machine direction movement of a point on the surface of a soft roller constructed according to the instant invention as the point proceeds through the pressure nip. The combination of sidewise distortion and machine direction distortion of the soft roller surface produces a resultant oblique compaction of the web and allows an isotropic sheet to be produced.

FIG. 4 shows one means of constructing the elastomeric band to achieve the desired flow of the elastomeric material in the nip area when the elastic surface of the band is indented by the hard roller. Annular grooves or slits 40 are cut in the surface of the band. The slits lie at an oblique angle to the plane of the surface of the elastomeric band as illustrated in FIG. 4*a* which is a fragmentary cross section of the roller of FIG. 4. The angle of the grooves may vary depending upon direction of maximum distortion desired. This construction results in a sidewise movement of the elastic material (rubber for the purposes of this example) when the rubber is indented by the hard roll. This movement may be seen by comparing FIG. 4*b* which shows the rubber indented and FIG. 4*a* which shows the rubber before being indented against the surface of the hard roll. Each land of rubber 41 will tend to lean into the adjacent slit and will thus be displaced along the axis of the roller 12. The width of the grooves is not critical. However, they should be no wider than is necessary to allow the sliding of the rubber lands.

When the rollers are at rest, the major flow of the rubber caused by the nip indentations is along the axis of the roller 12. When the apparatus is running, there will be present the distortion of the rubber caused in the machine direction due to the fact that the soft roller is undersped in relation to the speed of the hard roller. The direction of maximum distortion of the rubber then will be in a direction oblique to the machine direction. That is, the line of maximum distortion of the rubber surface will lie somewhere between the machine direction and the cross-machine direction, being in effect the resultant of the axial movement of the rubber caused by the slits and the forward or machine direction movement of the rubber caused by the dragging of the rubber due to the slower speed of the rubber surface in relation to the surface speed of the hard roll. Since the web will tend to follow the movements of the rubber surface in the pressure nip, the web will be compressed in an oblique direction as the rubber recoils along the same lines it was elongated.

The concept of extension and recoil of the rubber in the pressure nip is well known, but a few words may be worthwhile here to review the mechanism by which compression of a web occurs in a compacting nip. At the entrance to the pressure nip the rubber exhibits maximum distortion or elongation. In the S. L. Cluett compactor this elongation is in the machine direction. In the instant invention it is in some direction other than the machine direction as discussed above. The elongation is the result of the faster moving hard roller trying to pull the soft roller along with it. Because the soft roller is positively driven at some predetermined surface speed which is slower than the surface speed of the hard roller, the elastic surface is stretched at the entrance to the pressure nip. This stretching causes a bead or hump of rubber to form at the outlet of the nip. As the rollers rotate, the rubber surface is constantly adjusting to this condition by slipping backward through the nip. This slipping has been termed the "recoil." Once the two rollers are brought up to speed an equilibrium is reached wherein the rubber is stretched at the inlet to the nip and a "permanent" hump is formed at the nip outlet with the rubber surface constantly recoiling as it attempts to adjust to this bias condition.

FIGS. 5 and 5*a* show an alternate means of constructing the elastomeric element to achieve oblique movement of the rubber surface. Here grooves or slits are cut in the elastic band so that they run from edge to edge of the band. Since the slits run on a bias they may be normal to the surface of the elastomeric element.

FIGS. 6 and 6*a* show still another means for achieving maximum distortion of the rubber to occur in other than the machine direction. Movement of the rubber on the surface 13*b* of the elastomeric element 13 is restrained by relatively inelastic cords 60 located in the body of the elastomeric element just below the rubber surface. The cords lie obliquely across the elastic band, running from edge to edge as in the case of the slits shown in FIG. 5.

FIG. 6*b* is a diagram illustrating the way the restraining cords would distort in the pressure nip area. Line A shows a typical cord relaxed, and lines B and C show the cord distorted. The various forces and directions of movement are shown in the figure.

A variety of other methods could be used in addition to those shown in the figures to achieve the same result. For example, instead of using cords, discrete hairlike segments of a relatively inelastic material could be embedded in the body of the rubber. The individual segments would be orientated so that a majority lie substantially across the elastic band and at an oblique angle with respect to the machine direction. The segments would be relatively inelastic compared with the rubber and would produce a restraining effect on the elastomeric element in their direction of orientation.

The above-discussed embodiments provide for controlling the direction of the flow of rubber in the nip area so that shrinking of the web and therefore extensibilizing may take place in a direction other than the machine direction. In prior art devices, the major distorting forces are exerted in the direction of movement of the rollers, and so the primary distortion of the rubber tends to be in that direction. In the ABC compactor, the direction of shrinking is controlled by locating the pressure nip rods at various angles. In the instant invention, the elastomeric element is constructed so that the rubber will flow in the desired direction. There is no need to rely on the disposition of nip rods in relation to the web. The desired rubber distortion or "flow" is achieved by making the line of least resistance to rubber flow coincident with the direction of shrinking desired. Said another way, the rubber band is so constructed that the machine direction force exerted by the moving rollers is in essence redirected because it will have the greatest distorting effect in the direction of least restraint. The structure of the elastomeric element is such that the direction of distortion of the rubber surface is controlled by the orientated structural components which may be such as those described above. The components must be disposed in such a way that they produce a restraint in some given direction. In order for the restraint to effect compressing of the web in other than the machine direction, the components must be placed in such a way that their orientation is oblique to at least one of the principal axes of the pressure nip. The principal axes are three in number and are mutually orthogonal, each one being perpendicular to the plane formed by the other two. One of the principal axes is the tangent to the surface of the soft roller which is parallel to the axis of the roller, that is, a line from end to end along the length up the roller. Another is a line normal to the elastic surface of the roller intersecting the first-mentioned tangent line. And the third is the tangent to a point on the roller which tangent is perpendicular to the plane formed by the first two mention. In a double-roll compactor the axes are commonly referred to as the cross-machine direction, the normal direction and the machine direction. Such designations are for the most part correct because, as previously discussed, the nip lies substantially at right angles to the machine direction. Where an endless blanket is employed in conjunction with a hard roller and a pressure bar, the principal axes may be considered to be defined with reference to the hard roller. The principal axes of the nip then become the tangent of the hard roll surface which is parallel to the axis of the roller, the radius of the hard roll, and the tangent normal to the plane formed by the tangent first mentioned and the radius. The defining of the principal axes of the double roll unit also could be defined with regard to the hard roll since the surface of the elastomeric element in the pressure nip in any event is substantially coincident with the surface of the hard roller.

FIG. 7*a* shows the location of the principal axes of the nip in relation to the rollers.

The idea is to create a stress distribution in the rubber under nip loading which is clearly oriented in a predetermined direction. Preferably this direction forms with the cross-machine direction an angle of 15° to 75°, and ideally an angle of 45°, in order to achieve more nearly a truly isotropic sheet in two compacting passes.

Since the primary object of the instant invention is to produce isotropic extensibility so that the increased extensibility may be fully utilized, the web must be compacted in two or more crossing directions. This is accomplished by compacting the web first at, for example, 45° to the running direction of the paper in a first compactor and then at a direction that is at right angles to the first compacting direction by passing it through a second compactor unit. Alternatively, either of the above compactors could be simply a unit built according to the S. L. Cluett invention. However, it can be appreciated that to approach more closely a situation where the stretchability and toughness is equal in all directions, the second unit should preferably compact in a direction perpendicular to the direction of compaction of the first unit.

The result of the arrangements described above is a change in direction of the paper as it leaves the pressure nip. A continuous bend is put in the paper, and it might first appear that the web would therefore be stretched on one side. However, as shown in FIG. 7, because the web **10** is also shrunk, there is no net stretching associated with the bending. Referring to FIG. 7, A_1 represents a segment of the web surface before compacting, and A_2 represents the same segment after the web has passed through the compacting nip. Segment A_1, before compaction, will be longer than or at least equal to length A_2, after compaction.

FIG. 8 is a chart showing the effect of compaction according to the instant invention. The dotted line shows the primitive extensibility of the web after one pass and the full line shows the extensibility after two passes. Zero degrees is the cross-machine direction. The chart was obtained by cutting test specimens at 30° increments between 0° to 150° measured counterclockwise from the direction of the samples. For purposes of illustration symmetry was assumed for the product between 180° and 360°. The extensibility after one pass shows a maximum stretchability in a direction approximately 60° from the machine direction. The curve was generated by using a soft roll of about 40 Shore A Durometer hardness with restraining reinforcing running across the blanket at an angle of 45°.

The moisture of the sheet may vary according to the results desired and the various other parameters such as amount of overspeed of the hard roll and the nip pressure. The sheet moisture may be from about 30 to 75 percent. Until recently it was thought that a maximum of about 40 percent moisture by weight was an optimum operating range. However, it has been discovered that use of special low friction surfaces on the hard roll will allow compaction up to around 75 percent moisture. At low moistures it has been found that pronounced wrinkles may appear in the compacted sheet and, in some instances, such wrinkles are considered undesirable.

The hardness of the soft roll surface may vary considerably. A Shore A Durometer hardness of between approximately 10 to 70 has been used successfully. However, this can be altered depending on the type of surface desired on the finished web. As the hardness decreases, assuming other parameters remain constant, the wrinkles on the surface will become more pronounced.

The drum overspeed is a parameter which can be varied according to the amount of shrinking desired in a single pass through the compacting nip. This does not appear to be a critical parameter, and persons familiar with mechanical compaction will be readily able to choose an optimum overspeed in any given situation. There must, however, be some overspeed for shrinking to occur. Overspeeds of up to 50 percent have been used with satisfactory shrinking taking place.

Although the present invention has been described with reference to specific apparatus, it will be appreciated by a person skilled in the art that a wide variety of changes may be made without departing from the scope of the invention. For example, certain features of the apparatus may be used independently of others and equivalents may be substituted for the apparatus elements, all within the spirit and scope of the invention.

I claim:

1. Apparatus for controlling the direction of mechanical compaction of paper and similar fibrous webs including, a cylindrical hard surfaced roller, an elastomeric surfaced element, means supporting the elastomeric surfaced element in such a way that the surface of the elastomeric element forms a pressure nip area with the surface of said roller, and the surface of said element adapted to move at a somewhat less linear speed than that of the surface of the hard roller in order to advance and compact the web, said elastomeric surfaced element including a plurality of structural components all similarly orientated in the elastomeric element so that when the elastomeric surfaced element is in the pressure nip area, the structural components lie at an oblique angle of not less than 15° but not more than 75° with respect to at least one of the principal axes of the pressure nip; and said structural components being so located as to cause maximum elongation of the elastomeric surface to occur in a direction which lies at said oblique angle to the axis of the hard surfaced roller and along the elastomeric surface.

2. Apparatus for controlling the direction of mechanical compaction of paper and similar fibrous webs including, a hard surfaced roller, an elastomeric surfaced element, means supporting the elastomeric surfaced element in such a way that the surface of the element forms a pressure nip with the surface of said hard roller, and the surface of the elastomeric surfaced element being adapted to move at a somewhat less linear speed than the surface of the hard roller in order to advance and mechanically compact the web, the pressure nip inlet lying substantially at right angles to the edges of the advancing web, and means included in the elastomeric surfaced element for causing maximum elongation of the surface of the elastomeric surfaced element, under nip loading as the element advances through the nip, in a direction which lies at an oblique angle of not less than 15° but not more than 75° with respect to the axis of the hard surfaced roller and along the surface of the elastomeric surfaced element.

3. Apparatus for controlling the direction of mechanical compaction of paper and similar fibrous webs comprising, a hard surfaced roller, an elastomeric surfaced roller, said rollers having parallel axes and located so as to form a pressure nip, and said elastomeric surfaced roller adapted to move at a somewhat less peripheral speed than that of the hard roller, the elastomeric surfaced roller including a thick elastomeric outer layer firmly mounted on a rigid core, and the elastomeric outer layer having a plurality of structural components

orientated at an oblique angle of not less than 15° but not more than 75° with respect to the axes of said rollers such that maximum elongation of the elastomeric surface is caused to occur in a direction which lies at said oblique angle to the axes of the rollers and long the elastomeric surface.

4. The apparatus of claim 1 wherein the elastomeric surfaced element is a thick endless rubber belt firmly attached to a hard roller.

5. The apparatus of claim 4 wherein the structural components are relatively inelastic cords disposed below the surface of the belt and running obliquely across the width of the belt from edge to edge.

6. The apparatus of claim 4 wherein the structural components comprise lands having adjacent cutaway portions and running generally obliquely with respect to the edges of the belt.

7. The apparatus of claim 4 wherein the structural components comprise lands having adjacent cutaway portions, the cutaway portions running annularly and being cut at an oblique angle to the surface of the belt.

8. The apparatus of claim 2 wherein the means in the elastomeric element comprises relatively inelastic members disposed generally at an oblique angle with respect to the cross-machine direction.

9. The apparatus of claim 2 wherein the means in the elastomeric element comprises relatively inelastic members disposed generally at an oblique angle with respect to the surface of the element.

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