Jan. 24, 1967 T. G. COOPER ETAL 3,300,368

CREPED SHEET MATERIALS AND THE PROCESS OF PRODUCING THE SAME

Filed Dec. 11, 1964 2 Sheets-Sheet 1

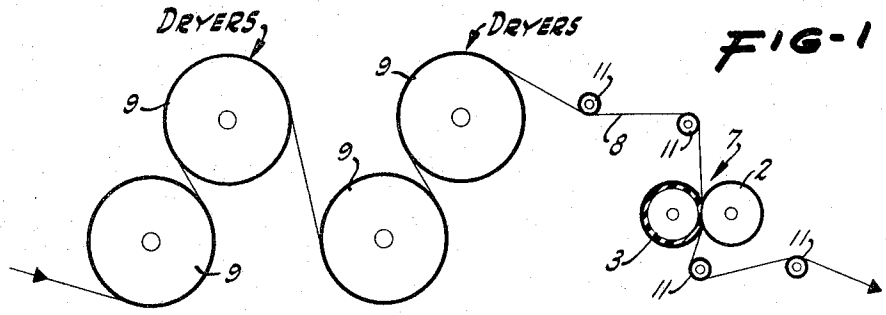


FIG-1

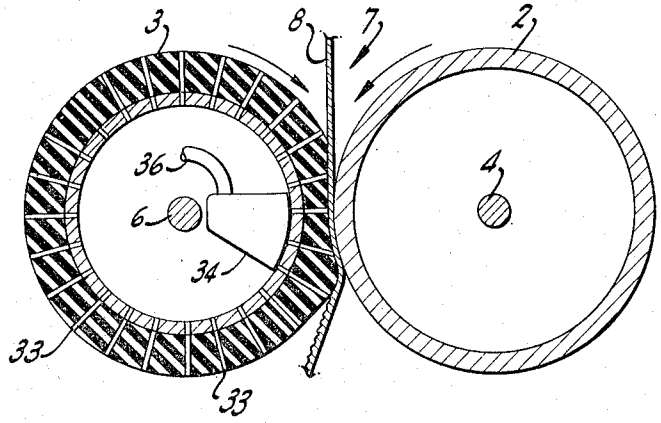


FIG-2

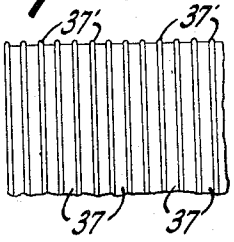


FIG-3

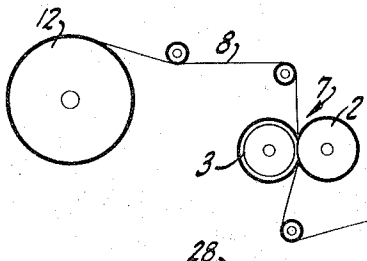


FIG-4

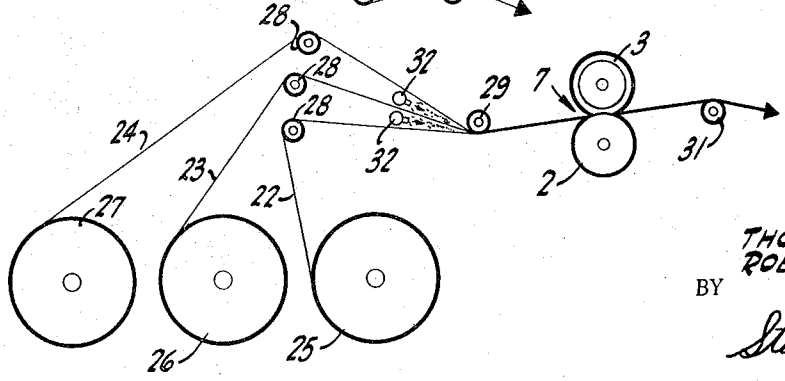


FIG-5

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CREPED SHEET MATERIALS AND THE PROCESS OF PRODUCING THE SAME

Filed Dec. 11, 1964 2 Sheets-Sheet 2

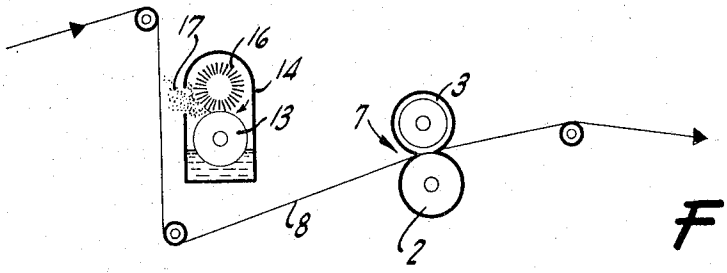


FIG-6

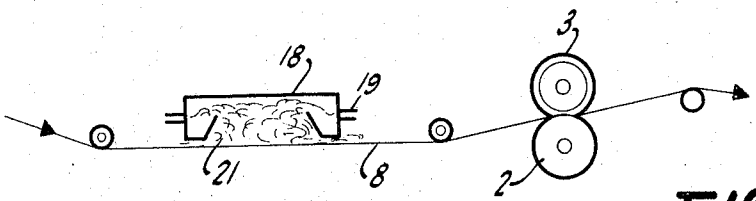


FIG-7

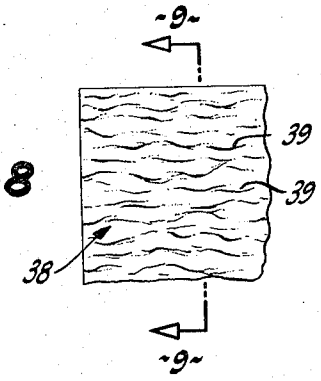


FIG-8

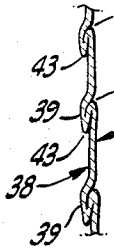


FIG-9

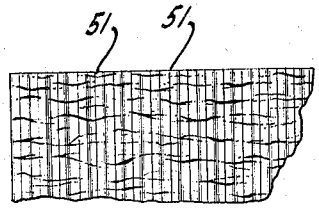


FIG-10

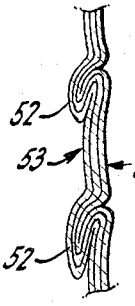


FIG-11

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United States Patent Office

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CREPED SHEET MATERIALS AND THE PROCESS OF PRODUCING THE SAME

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Filed Dec. 11, 1964, Ser. No. 417,547

16 Claims. (Cl. 161—128)

This application is a continuation-in-part of applicants' co-pending U.S. application Serial No. 291,241, filed June 28, 1963, for "Extensible Sheet Materials and the Process for Producing the Same," now abandoned; the invention relates to creped sheet materials and a process for producing the same. More particularly, it relates to the creping of non-woven sheets in the substantially dry state, especially paper, to render them stretchable, and at the same time provide a superior product of this kind having greater stretchability, flexibility, and toughness than the uncreped sheet material, and greater strength and toughness than such sheet materials having comparable stretchability but which are creped by known methods.

Stretchable papers used in the manufacture of toweling and tissue as well as for other purposes have been manufactured by various processes. Some paper creping processes rely upon a sort of compressing or gathering of the paper web during its manufacture as the paper web advances through a papermaking machine and while the paper is plastic because it still contains a substantial amount of moisture. This type of creping takes place by a retarding or rearranging of the paper or the pulp fibers before the fibers have completely set and formed strong inter-fiber bonds. These processes produce crepe wrinkles on the paper oriented in the cross-machine direction of the paper so that the paper is made stretchable lengthwise of the web, or in the with-machine direction with little and hardly beneficial results in the cross-machine direction of the finished product. This is also true, for example, of ordinary toweling or tissue blade-creped in a substantially dry condition, which are characterized by low strength.

In conventional techniques for producing dry-creped toweling and tissue products, a doctor blade or knife is used to peel the web from a dryer drum or so-called can to which the dry paper is adhered before the peeling. In such procedure, because the paper is substantially dry, the cellulosic fibers are completely bonded together. Consequently, the paper structure suffers severe damage from the action of the blade with consequent considerable loss of strength. This destructive effect becomes more prominent, for example, in the case of a fine grade of toilet tissue, creped from a dryer can in substantially dry condition. The exceptional softness which is desired in such product, and imparted by this treatment, is a direct result of the breakdown of fibers and inter-fiber bonds from the sharp creasing action of the doctor blade. The desired softness, then, is gained at the expense of the general strength properties.

Another blade-creping technique, used primarily for toweling grades, involves the doctoring of the web from a dryer can while the paper still has sufficient moisture content so that cellulosic fibers have not yet been completely bonded together or set. Such wet blade-creping

method is used primarily to obtain an increase in stretch with accompanying loss of strength and to give the paper a textured surface. However, because the physical damage to the paper structure is more limited, no large gains in softness are achieved.

Other methods of creping have been described, as exemplified in U.S. Patent to Back et al., No. 3,104,197, dated September 17, 1963, wherein the elastic property of rubber or like material is employed for imparting a creped effect in one or both directions of the paper. In such method, a moist paper web of above 20% moisture content, whereby the paper is still plastic, is creped by passing through a nip formed by a hard roll and an elastic roll located in the drying section of a paper machine. The creping action is effected on the moist web before the fiber-to-fiber bonds have been completely established by setting or bonding thereof.

As is well recognized, bonding of cellulosic pulp fibers in the formation of paper occurs as a result of previous cellulosic pulp refining processes which fibrillate the fibers, namely, effect formation of fine, hair-like strands. In the papermaking process on the papermaking machine, these strands form an intimate molecular bond therebetween after the paper web or sheet has been dried to normal paper moisture content of about 5 to 6%. Thus, after paper has been dried to such normal moisture content, it has physical properties markedly different from those of still moist plastic paper wherein inter-fiber bonding has not yet been completed.

Summarizing this invention, it has now been found that creping of paper can be effected by differential frictional forces acting simultaneously on opposite faces of the paper web even after the paper has been completely formed, namely, after complete inter-fiber bonding of the cellulosic pulp fibers has occurred in the paper as a result of substantially complete drying thereof. Such differential frictional forces are advantageously applied by the type of apparatus disclosed in the aforementioned patent wherein the web is passed between the nip of a rotatable hard roll and an opposite rotatable elastic roll, the opposed surfaces of which move in the same direction with the hard roll operating at a greater surface speed than the elastic roll.

Paper dried to normal moisture content of about 5 to 6% can thus be processed. In some instances, for the purpose of enhancing the creping, particularly when webs of paper are laminated together as explained hereinafter, a small amount of moisture suffiicent to dampen the paper can be added thereto in an amount which does not affect the already formed inter-fiber bond. If moisture is added, the total amount of moisture, including the normal amount in the paper, should not exceed about 15% because then the paper may be too pliable to produce the desired creping effect obtainable with paper wherein the inter-fiber bond has been established. In any event, the paper in all instances is substantially dry in contradistinction to previously undried paper webs wherein the moisture content is such that the cellulosic fibers have not yet been strongly bonded together or set.

The creping of the paper imparts stretchability softness, bulk and good feel thereto which are particularly advantageous in so-called sanitary type papers, such as toilet tissue usually of a basis weight before the creping in the

order of 10 to 13 pounds per ream (3,000 sq. ft.), or paper toweling usually of a basis weight of about 35 to 40 pounds per ream before the creping. However, the invention hereof is applicable to heavier grade papers, such as wrapping paper and paper for multi-ply paper sacks. Also, non-cellulosic webs, such as metal foil, nylon and plastic film, for example, polyethylene or polypropylene film, can be effectively dry-creped by the process hereof, especially when such noncellulosic webs are relatively thin, namely, about ½ mil to 2 mils in thickness.

Stretchability of the web is a function of the amount of creping, namely, the more it has been creped, which results in shortening of the web, the greater the stretchability. As previously related, dry paper has been previously conventionally creped by a doctor blade. The peeling action effected by such blade as the paper is removed from the drying surface to which it has been adhered, results in fiber rupture with consequent loss of paper strength. Although the dry creping procedure hereof results in loss of strength compared to the smooth-surfaced uncreped paper of the same type and basis weight, such loss is materially less compared to dry blade-creped paper having the same degree of stretchability. Thus, for stretchable paper toweling and toilet tissue which have a stretchability of about 15% to 20% as a result of creping, blade creping will generally result in a loss of tensile strength (called tensile in the art) and rupture of about 55% to 65% compared to a loss of only about 15% to 30% by the process of this invention on paper of the same type and basis weight.

To increase stretchability in a cross-machine direction, the substantially dry paper web may be simultaneously embossed while being creped, in the manner disclosed in the aforementioned patent. Thus, separate embossing processes which are required as a separate step in present dry blade creping operations when the paper web is also to be embossed are obviated.

The process of the present invention thus has the advantage of producing a creped, dry sheet material which possesses the softness and surface feel of dry blade-creped products but without incurring the severe strength losses caused by the blade. In other words, the products of the invention are softer and more pliable than wet blade-creped products and have better strength and toughness than dry blade-creped products. These characteristics are due to the fact that a sheet material, such as a substantially dry paper web, is bunched and compacted by relatively gentle forces of the elastic surface in the present invention where the creping is advantageously accomplished by a controlled interaction between a hard surface and an elastic surface. As previously mentioned, this is in contrast to the use of a doctor blade to effect compaction, where the web is violently scraped from a dryer can by the blade. In short, the substantially dry-creped paper of the present invention is stronger and tougher than sheet paper creped to the same degree of stretchability and at the same moisture level using a conventional doctor blade method of creping.

An important optional feature of the present invention is the capability of mechanically laminating together two or more plies of sheet materials, such as paper, foil, plastic film, and combinations thereof, simultaneously with the creping, or with the creping and embossing operation. This feature further simplifies the production of multi-ply sheet materials, such as towel and tissue products, since the laminating is done without the aid of adhesives or severe conventional embossing operations, as the creping folds interlock the plies of a multi-ply sheet together.

The creping of such materials as metal foils or plastic films is not practical with the conventional methods, such as blade-creping techniques, due to the problems associated with adherence of the foil or film to a creping drum and the severe action of the doctor blade which would easily tear and rupture the material. The present invention, by virtue of the gentle creping action of a soft elastic roll, can crepe and compact such foil or film materials without rupturing, tearing, or pinholding, and has been found particularly advantageous in the creping of nylon.

From the preceding, it is seen that an object of the present invention is to provide a dry-creped sheet material which is stretchable in both with-machine and cross-machine directions, which possesses toughness and stretch in all directions, and in the case of paper possesses softness and absorbency in excess of those of the untreated sheet.

Another object of the present invention is to provide a stretchable and embossed dry-creped sheet material and process of forming the same by simultaneously dry-creping and embossing a dry sheet to give it stretchability in all directions.

Another object of the invention is to provide a web and process for making the same, which web can be made by an apparatus low in original cost, simple, and inexpensive to operate and capable of producing a uniformly compressed creping in a dry web and simultaneously embossing the web to produce any one of numerous patterns therein and to create cross-machine stretchability of the web.

A further object of the invention is to provide a stretchable, laminated and dry-creped sheet material without the use of adhesives, and a process therefor by simultaneously dry-creping a plurality of plies of a web.

Another object of the invention is to provide a stretchable, embossed and laminated dry-creped sheet material without the use of adhesives, and a process therefor by simultaneously dry-creping and embossing plies of a web.

A still further object of the invention is to provide a process of making creped sheet material, such as paper, by passing a substantially dry sheet material through a nip formed by a hard roll and an elastic roll, thereby producing a tough, creped sheet material characterized by good strength and high stretchability.

Other objects will become apparent from the following, more detailed description.

The term "substantially dry," as used in this application in conjunction with paper, denotes a sheet in which the inter-fiber bond has occurred but which may have been additionally moistened but only to the extent that the initially dry character of the sheet is unaffected, the total moisture content being up to about 15%; and in the case of other sheets, such as metal foil and plastic film, the dry state or with slight surface moisture added in an amount unaffecting the dry character thereof.

The term "sheet material" as used herein includes all non-woven crepable flexible materials, such as fibrous sheets including paper, and non-fibrous sheets including nylon, plastic films, and metal foils, as well as combinations thereof. If the materials are fibrous, such as paper, the creping effect is caused by the net result of bending of the fibers, the compaction thereof and wrinkling or folding of the sheet. These three factors are, of course, the source of the stretchability of the sheet materials. Textiles, which are of woven fibers, however, are excluded herein from the term "sheet material" since the theory of shrinking textiles and the products thereof are completely different than those of the present invention.

Reference will now be made to the accompanying drawings for a more detailed description of the invention, in which:

FIG. 1 is a schematic elevational view illustrating the location of the creping apparatus at the end of a conventional papermaking machine, namely, after the last dryer roll at which complete inter-fiber bond has occurred;

FIG. 2 is a diagrammatic sectional view of the principal creping elements of the apparatus of the present invention;

FIG. 3 is an elevational view of a part of the hard roll of FIG. 2, illustrating a modification for effecting embossment;

FIG. 4 is a schematic elevational view illustrating the creping apparatus in association with a roll of sheet material to be creped;

FIG. 5 is a schematic elevational view illustrating the creping apparatus employed for laminating a plurality of webs of sheet material;

FIG. 6 is a similar view illustrating a brush type applicator for dampening a sheet material before creping;

FIG. 7 is, likewise, a similar view illustrating steaming;

FIG. 8 is a fragmentary plan view illustrating the creping effect on sheet material;

FIG. 9 is an enlarged more or less schematic cross-sectional view taken in a plane indicated by line **9—9** of FIG. 8, illustrating the character of creping performed by the process hereof;

FIG. 10 is a fragmentary plan view, similar to FIG. 8, illustrating creped and embossed sheet material; and

FIG. 11 is an enlarged more or less schematic cross-sectional view of a multi-ply sheet in which the plies are secured together without adhesive by interlocked crepe folds effected by the process hereof.

With reference to FIG. 2, the type of apparatus employed for the practice of the present invention includes a two-roll press consisting of a substantially smooth-surfaced, hard roll **2** and an elastic mass, namely, a soft elastic roll **3**, such as a rubber-covered roll, rotatable about shafts **4** and **6**, respectively. These rolls are engaged under a pressure to form a nip **7** through which the web **8** to be creped is conducted. The hard roll and the soft roll are rotated by suitable drive means so that their respective opposed surfaces travel in the same direction through the nip, as indicated by the direction arrows in FIG. 2, but with the hard roll travelling at a greater surface speed than the soft roll. Thus, soft roll **3** in engagement with one face of the web applies a resilient force simultaneously pressing the opposite face of the web against hard roll **2**.

In the case of paper, web **8** of such substantially dry paper may be fed into the nip directly after leaving the final dryer cylinders **9** at the dry end of a papermaking machine whereat the paper has been dried to final moisture content of about 5 to 6%. Conventional guide rolls **11** are provided ahead and beyond the creping apparatus; and after being creped, the paper is wound in a roll by conventional winding means, not shown. The resulting product of this process is a substantially dry web creped or creased on both sides, but with the side in engagement with the elastic roll having a pronounced crepe, and the side contacting the hard roll relatively smoother than the opposite side, as explained more fully hereinafter.

Instead of effecting the creping operation as the paper leaves the final dryer cylinders, substantially dry paper having the usual ambient moisture content of about 5 to 6% may be unwound from a roll **12** thereof, as shown in FIG. 4, and passed through nip **7** of the creping apparatus. Instead of a paper roll **12**, such roll may be nylon, foil, plastic, or any other type of flexible, non-woven sheet or web material capable of being creped.

When it is desired to dampen the web, for reasons explained later, this may be done by a conventional brush applicator as illustrated in FIG. 6, wherein a kiss roll **13** is rotatable in water tank **14**, and cooperates with rotatable applicator brush **16** to spray moisture through opening **17** in the tank onto one surface of web **8**. FIG. 7 illustrates another modification for applying moisture wherein a steam chest **18** is provided over web **8** into which steam is introduced through piping **19**; the bottom of chest **18** being open at **21** to expose a surface of the web to the steam.

FIG. 5 depicts how the creping apparatus may be employed for laminating webs of crepable material **22**, **23** and **24**. The respective flexible webs are simultaneously unwound from rolls **25**, **26** and **27**, pass over guide rolls **28** and are brought together in face-to-face relationship under guide roll **29** ahead of the creping zone or nip **7** from which the laminated, creped, multi-ply sheet passes over guide roll **31** to a conventional roll winding reel (not shown). If desired, for the purpose of facilitating the laminating operation, moisture may be added to at least one of the webs, and advantageously to the adjacent surfaces of the webs by means of steam emitted from piping **32**.

As illusrated in FIG. 2, if it is desired to improve adherence of the web to the surface of the rubber roll **3** as it passes through nip **7**, suction may be employed for such purpose by providing a multiplicity of perforations **33** in the rubber roll, and providing a stationary suction box **34** mounted within roll **3** adjacent nip **7**. Suction means, not shown, communicating with the suction box through suction line **36** serves to enhance the adherence of the web to the rubber roll but such suction means may be omitted as the rubber itself under the pressure at the nip will adhere sufficiently to the web to perform the creping or wrinkling of the web.

For increasing stretchability in the cross-machine direction, the web may be simultaneously embossed with the creping operation. Such embossing may be accomplished by parallel circumferential grooves **37** in the hard roll, which form ribs **37'** projecting from the periphery of the roll. These ribs result in forming indentations in the web as it is creped. The size and space of the ribs may be varied; and other embossing patterns may be employed to obtain a like effect.

In operation of the creping rolls **2** and **3**, friction forces transmitted through the web from the faster-moving hard roll **2** to the soft elastic roll **3** cause the soft surface to stretch and speed up as it passes into the nip **7**. As the soft surface is elongated and pulled into the nip, the main body of the soft surface is caused to deform tangentially in the direction of web travel. At some point after the entrance into the nip, the stretched soft surface reaches the speed of the hard holl and the web; and the soft surface, the web, and the hard roll surfaces become temporarily locked in a state of traction without relative motions. Once this traction state is established, the soft surface has a greater frictional bond with the web than does the hard roll surface. As the traction state continues further into the nip, the tangential deformation in the soft roll surface builds up rapidly increasing internal stresses which tend to oppose further deformation.

At some point in the middle region of the nip, the reactive forces, built up by deformation in the soft surface, overcome the static friction limits at the hard roll-web interface, and slippage opposite to the direction of web travel is initiated at this interface. Once the traction state is broken in the area of slippage in the nip, the soft roll surface exhibits two distinct actions, i.e., the stretched soft surface contacts toward its relaxed state to assume its original length while slipping backward with respect to the direction of the motion of the hard roll surface. This relative or differential motion between the roll surfaces continues until the section of the soft surface under consideration leaves the nip. Throughout such differential motion the web is carried with the soft roll surface while the slippage occurs between the web and the relatively smooth-surfaced hard roll causing wrinkling, and simultaneous compaction of the web along one face or surface in engagement with the hard roll, and producing a pronounced creped or wrinkled effect on the face of the web contacting the soft surface. Because of such compaction against the hard roll, a smoother effect obtains on the side contacting such hard surface.

FIGS. 8 and 9 depict schematically the creping effect obtained as a result of the above-described action of the creping rolls. It will be noted that the face **38** of the web in contact with soft elastic roll **3** is gathered into a succession of longitudinally spaced and transversely extending folds or wrinkles **39**, all extending in a cross-machine direction and with such folds **39** projecting in the same longitudinal direction as a result of the compres-

sive forces between rolls 2 and 3. The opposite face 41 of the web in contact with the smooth-surfaced hard roll is formed with transversely extending spaces 42 resulting from folds 39. However, because of the smoothness of the hard roll 2 and the compaction effected by the pressure of rubber roll 3, such opposite face 41 is mashed down on the hard roll and simultaneously smoothed out against such roll. Hence, it is smoother than wrinkled face 38. In this connection, it will be noted that because of the increased thickness at the crease lines 43 of folds 39 definite protuberances exist on face 38 which render it rougher than opposite face 41. Varying creping effects can be obtained depending on the differential speed between the rolls, the softness of the rubber roll, thickness of the web, and compressive forces between the rolls.

The two primary elements of the apparatus used for the present invention, the hard roll 2 and the soft elastic roll 3 perform an itnerdependent and active function in the creping of the web. Furthermore, the hard roll of the present invention cannot be advantageously replaced by a stationary shoe or any other such stationary element. The necessary deformation in the surface and the body of the elastic roll covering is directly and forcibly caused by the action of the faster-moving hard roll, and not by the geometric configuration of any of the machine elements, such as a stationary concave or convex shape of a rubber belt. The rebound action of the soft surface from its deformed state, which causes creping in the web material, results from a sudden unbalanced force system as the stored compressive energy in the rubber covering overcomes the friction forces at the interface between the web and the hard roll. This action is quite different from the compacting action of the rubber belt-hard roll combinations, where compaction or shrinking of the web is the direct result of a change in the geometry of the belt course.

The differential speed of the two rolls is advantageous in the manner in which the degree of compaction or creping can be changed. To increase the degree of compaction in the rubber belt devices, either the thickness of the belt or the geometry of the belt course must be changed. With present invention, the degree of creping, under any given conditions, may be changed over a very broad range by merely adjusting the differential speed while passing the web through the nip 7 only once. This is another distinguishing factor from processes which employ a hard roll-belt apparatus. In these processes a number of treatments by such hard roll-belt apparatus may be necesasry in order to attain a desired degree of stretchability.

The degree of stretch induced in the with-machine direction of the web by the process of the present invention is primarily dependent on the speed differential between the surfaces of the hard and soft rolls. The speed differential may vary within a wide range, for example, a 40% differential based on hard roll speed has been successfully employed in the process of the invention resulting in stretch levels as high as 67% in the with-machine direction of the treated web. A practical minimum speed differential exists below which the forces of deformation in the soft surface do not build up high enough within the creping zone of the nip to cause the necessary slippage between roll surfaces and consequent creping action. For best results, the minimum surface speed differential between the two rolls should not be much below about 5%.

For any given speed differential, an operating range of nip pressure is desirable within which the process will function to best advantage. Variations of nip pressure within such operating range have little effect on the process and the product of the invention. However, if the limits of this range are exceeded it will result in a complete or partial loss of the creping action. As the speed differential increases, the effective range of nip pressure also is increased. For example, at a speed differential of 12%, the preferred nip pressure is about 40 pounds per lineal inch, while at 30% speed differential, the pressure may be about 170 pounds per lineal inch. Variations in the nip pressure depend upon variables, such as roll diameters, the hardness of the elastic surface and web characteristics. The pressure between the rolls at the nip may be relatively light. Pressures as low as 10 pounds per lineal inch have produced satisfactory results. Generally, with a surface speed of the hard roll at about 5 to 50% greater than the surface speed of the soft roll, the nip pressure may vary from about 25 to 400 pounds per lineal inch.

Various materials may be used for the hard roll surface. Exemplary of these are: mild steel, Microrok (an artificial stone comprising a siliceous aggregate adhesively bonded by a synthetic resin), granite, or other stones finished to a smooth but not highly polished surface. The choice of materials is not critical as long as the surface friction coefficient is such as to provide creping in cooperation with the elastic roll.

The softness of the elastic material, such as rubber, on the soft roll contributes to the successful manufacture of the product of the present invention. The softness of the elastic material as measured by the conventional Shore durometer hardness test may vary generally within the range of from 10° to as high as 55°, depending on the material being creped. For metal foil and strong paper, such as 30 to 40 pound kraft wrapping paper, the higher 55° hardness can be employed. Above a Shore durometer hardness of 45°, the power requirements for driving such harder roll may be too great for economical operation. Hence, it is preferred not to exceed a maximum Shore durometer hardness of about 45°. For less strong and thinner paper, such as toilet tissue, and for plastic film, such as polyethylene, a Shore durometer of, preferably, from 25° to 45° is desirable. The softer the elastic material, the less pressure is required to deform or stretch it and the coarser is the creping effect, which is generally desirable.

The surface finish of the elastic surface material, which is determined by abrading the same, such as by grinding, also affects the crepe characteristics, a fine grind yielding a fine crepe pattern while a coarser grind a coarser grain pattern. It is desirable to employ an elastic surface, such as a rubber covering, as soft as possible while still obtaining the desired creping results since this minimizes the power required for driving the creping apparatus, thus resulting in more economical operation.

As previously related, a web of a sheet material is treated by the process of the invention in a substantially dry condition. Paper webs are creped after the fiber bond has been formed with the paper in the substantially dry condition after their passage through the drying section of a paper machine, or from a roll of the completely formed dry paper. However, the paper may be slightly moistened prior to creping in the manner pointed out above to enhance the creping operation. Although not a necessary part of the process of the invention, a slight moisture addition to the web has numerous advantages: it serves to soften the web, resulting in a finer and more uniform crepe; prevents slippage between the individual plies in the creping of multi-ply webs; and reduces the build-up of static electrical charges in the web and soft roll surface.

If a moisture addition is applied, it should be in a slight amount so as not to affect the substantially dry character of the web. The total moisture content of a paper web should not exceed about 15%, otherwise the paper may be too plastic. The total amount of moisture, including the normal ambient moisture content of 5 to 6%, should preferably be between 5% and 10% based on oven dry weight of the web. In this manner no subsequent drying of the product is normally required. The web may be moistened prior to creping by conventional means, such as the aforedescribed steam showers and water showers from a brush-roll device, or water-air spray. For non-

paper webs, such as metal foil or plastic film, the addition of 2 or 3% moisture is sufficient.

The aforementioned embossing of the web is used primarily to increase the cross-machine stretch and toughness of the material, to enhance its caliper or bulk, and to provide a functional textured surface for certain end uses. If an embossing pattern is used on the hard roll, the sheet product will exhibit areas of relatively coarse, bulky crepe, corresponding to the voids in the pattern, and areas of relatively fine flat crepe corresponding to the surface lands or ribs of the pattern. Exemplary of such patterns are the spaced, parallel and longitudinal ribs 37' machined in the surface of a steel roll as shown in FIG. 3, or holes formed by drilling the surface of a steel roll which produce a product with circular areas of coarse, bulky crepe surrounded by a field of relatively fine, compressed crepe. Many other patterns in the embossed design may be used to obtain a desired embossed effect. Simultaneous creping and embossing produces a sheet material of a distinctly better quality than is obtained by creping and embossing in two separate steps. FIG. 10 illustrates a creped and embossed pattern wherein the sheet has longitudinal grooves 51 resulting from the ribs or lands 37'.

With respect to the simultaneous creping and laminating, or simultaneous creping, embossing and laminating, of two or more individual plies of substantially dry sheet material, the plies may be all of the same or different type of sheet materials including substantially dry paper. An inter-ply bonding is produced strictly from the mechanical action of the process without the necessity of employing adhesives. The inter-ply bonding is not a result of the embossing when the simultaneous embossing feature is incorporated in the process. The bonding is produced primarily by an interlocking of crepe folds or wrinkles and, in case of paper, paper fibers between individual plies. Such interlocking is illustrated schematically in FIG. 11 wherein a three-ply sheet is laminated with the plies secured together in face-to-face relationship, in the absence of an adhesive bond therebetween, by interlocked crepe folds 52. As with respect to the single ply sheet shown in FIG. 9, the creping on outermost face 53 engaged by the soft roll is more pronounced than on the opposite, relatively smooth outermost face 54.

The products of the present invention possess improved stretch and toughness in all directions over the base sheets, and improved softness and absorbency beyond the natural properties of the base sheets. The products also possess strength and toughness in all directions substantially greater than the strength and toughness of products, such as toweling and tissue papers, creped at a comparable moisture content by conventional creping methods, such as normal blade-creped papers. Papers having a stretch as high as about 67% in the with-machine direction and about 8% in cross-machine direction have been produced by the method and apparatus of the present invention.

By the process of the present invention, a wide selection of new and improved products, particularly paper toweling and tissue papers, can be provided. The greatest value of the invention lies in its potential use as an off-machine processing unit, capable of treating sheet materials, such as paper, in a substantially dry state. This feature, along with the great latitude of treatment effects that can be obtained by adjusting such process variables as hardness of the elastic roll, speed differential, and hard roll surface, allows a single unit to produce a wide variety of creped products. The apparatus employed in the present invention is relatively small, requires a small space, and is economical.

The products of the invention possess a substantially better softness and surface feel than conventional wet-crepe papers, and substantially better strength and toughness than conventional dry-creped papers. In addition, the simultaneous creping, embossing and laminating features of the invention cannot be accomplished with the conventional blade-creping techniques. For example, an interfold hand towel product may be produced, using the crepe-embossing feature, which possesses much better softness, general surface feel, and drape or pliability than commercial wet-blade-creped towels, and substantially better strength and toughness than commercial dry-blade-creped towels. In addition, the towel product possesses a surface texture uniquely resulting from the simultaneous creping and embossing which renders it extremely functional for the intended purpose of drying hands.

The simultaneous laminating feature of the invention makes it possible to produce multi-ply paper products without the use of adhesive bonding or expensive, maintenance-plagued, conventional embossing presses. The embossing design in the hard roll of the invention does not have to be machined or engraved with great precision, and has a much longer life than conventional embossing rolls.

The process of the invention, when applied to the manufacture of products such as tough, extensible creped foils, films, laminates, coated papers, provides a great number of improved packaging materials, extensible barrier materials, and unique decorative wrappings which could not be produced by any of the known processes. For example, a household aluminum foil creped according to the present invention was found to be much more formable than conventional foil products and much more resistant to ruptures and tears in use by virtue of its improved stretch and toughness.

In the case of paper to which the invention has found important applicability, particularly so-called sanitary papers, such as toweling and toilet tissue, there is considerably less loss in strength compared to conventional dry-blade crepe paper. For example, in the stretch range of 15 to 20%, dry-blade creping reduces tensile strength and rupture about 55 to 65% compared to the same uncreped paper, while the creping by the method hereof effects a much lesser loss of tensile strength and rupture of about 15 to 30%.

The above values change at different stretch levels, but the above relationship is substantially the same at varying stretch levels. At the same stretch level and moisture content in the substantially dry paper of about 5 to 6%, the creped paper hereof is about 1.6 to 1.9 times stronger than the same paper which is dry-blade creped, and the creped and embossed paper about 1.7 to 2.1 times stronger.

The following table is illustrative of particular embodiments of the invention. In the table, Sample A was Sulfite-Groundwood Sanitary Tissue and Sample B was Kraft Blue Windshield Towelling. The control in such table was uncreped paper, and the comparisons were the same paper but creped, and creped and embossed.

One important feature of the present invention which contributes to the manufacture of the improved products described herein is the fact that the creping of the web is effected quickly, under low pressure and particularly in an extremely short zone of treatment. That is to say, the entire creping process is accomplished at the recovery or recoil zone of the rubber roll 3. This zone is not substantially greater than, and may even be less than, one-half inch in the direction of the travel of the web. As an example, rolls having a 22-inch diameter will produce actual creping in a distance of about 0.3 inch. This distinguishes the present invention from known processes in which the creping of paper includes compressing it between a rubber belt and a hard surface over a considerably greater distance.

TABLE

	Sample A			Sample B		
	Control	Creped	Creped and Embossed [1]	Control	Creped	Creped and Embossed [1]
Basis Weight (lbs./ream)	12.7	14.6	14.2	25.0	34.0	37.4
Tensile Strength (lbs./in.) WMD	1.7	1.3	1.0	18.5	9.6	10.7
Tensile Strength (lbs./in.) CMD	1.3	0.8	0.7	10.4	10.1	11.4
Stretch, Percent WMD	2.4	13.0	11.2	1.9	45.2	55.7
Stretch, Percent CMD	1.6	3.2	3.5	4.5	5.3	5.4
Toughness, WMD (ft.-lbs./ft.^{2})	0.30	1.0	0.6	2.5	15.2	20.5
Toughness, CMD (ft.-lbs./ft.^{2})	0.14	0.18	0.13	3.7	3.9	3.1
Operating Conditions:						
No. of Plies		1	1		1	1
Moisture, Percent		7.5	6.2		9.0	7.8
Elastic Shore Durometer		37	30		37	37
Speed Differential, Percent		27	20		40	40
Nip Loading (lbs./lineal in.)		200	150		375	325
Hard Roll Surface Speed (ft./min.)		200	200		150	150
Roll Diameters		12	12		12	12
Draw to Reel, Percent [2]		10	9		25	26

[1] The embossment pattern on the hard roll was effected by 20 substantially parallel concentric ribs to the inch, each rib width being 0.025 in., the grooves therebetween 0.025 in. wide, with a depth of 0.025 in. However, as previously related, these dimensions may vary widely depending on the embossment pattern desired.

[2] The percent draw to reel indicates how much faster the creped sheet is drawn onto the winding reel therefor after leaving the nip of the creping rolls, than the speed of the sheet through the nip, as determined by the surface speed of the soft roll. This speed difference is not critical and can be the same as the speed of the sheet through the nip but is desirably faster in commercial operations, which results in removal of some stretch.

In this connection, the diameter of the rolls may vary within relatively wide limits preferably between 8 to 30 inches. However it is desirable that their diameters be relatively small so as to provide a short zone of treatment of the web in the nip 7 between the rolls. The speed of rotation of the rolls is also relatively immaterial and is governed by manufacturing conditions. Speeds of rotation such that the web travels through the nip at up to 1,000 feet per minute and as low as 50 feet per minute have been successfully employed with no difference in effect, and speeds of up to 2,000 feet per minute are feasible.

The present process may be carried out without heat during the creping process so that the hard roll may be operated at normal temperature, which extends the life of the rubber roll against which it acts.

The foregoing disclosure is not to be considered as limiting the scope of the invention since many variations may be made by those skilled in the art without departing from the scope or spirit of the following claims.

1. A process of making stretchable non-woven sheet material in the substantially dry state which comprises subjecting a web of such material in said substantially dry state to an elastic mass moving in one general direction in engagement with a face of said web while simultaneously moving and pressing said web against a substantially hard surface moving in the same direction as said mass but at a greater speed to compressively crepe said web while in said substantially dry state.

2. A process of making stretchable non-woven sheet material in the substantially dry state which comprises subjecting a web of such material in said substantially dry state to a moving resilient force applied to a face of the web by a rotatable elastic roll in engagement with said face of the web while simultaneously moving and pressing said web against an opposite substantially hard-surfaced roll, the opposed surfaces of said rolls being rotatable in the same direction and said hard-surfaced roll being rotatable at a greater surface speed than said elastic roll, to compressively form crepe folds on the face of the web in engagement with said elastic roll.

3. A process of making stretchable paper in the substantially dry state wherein inter-fiber bonding of the cellulosic fibers has completely occurred, which comprises subjecting a web of the paper in said completely inter-fiber bonded state to an elastic mass moving in one general direction in engagement with a face of said web while simultaneously moving and pressing said web against a substantially hard surface moving in the same direction as said mass but at a greater speed to compressively form crepe folds on the face of the web in engagement with said elastic mass.

4. A process of making stretchable paper in the substantially dry state wherein inter-fiber bonding of the cellulosic fibers has completely occurred, which comprises passing a web of the paper in said completely inter-fiber bonded state through a nip formed by a rotatable hard roll and an elastic roll with the hard roll driven at a surface speed greater than the speed of the elastic roll, and compressively creping said web in said nip by formation of successive crepe folds on the face of the web in engagement with the elastic roll.

5. A process of making stretchable non-woven sheet material in the substantially dry state which comprises subjecting a web of such material in said substantially dry state to an elastic mass moving in one general direction in engagement with a face of said web while simultaneously moving and pressing said web against a substantially hard surface moving in the same direction as said mass but at a greater speed to compressively crepe said web; and prior to such creping dampening said web in an amount below a total of about 15% moisture content without affecting its substantially dry character, to facilitate the creping thereof.

6. A process of making stretchable paper in the substantially dry state wherein inter-fiber bonding of the cellulosic fibers has completely occurred, which comprises passing a web of the paper in said completely inter-fiber bonded state through a nip formed by a rotatable hard roll and an elastic roll with the hard roll driven at a surface speed greater than the speed of the elastic roll to compressively crepe said web in said nip by formation of successive crepe folds on the face of the web in engagement with the elastic roll; and prior to such creping dampening the substantially dry web without affecting the inter-fiber cellulosic bond, to facilitate creping of the web.

7. A process for making a stretchable dry-creped sheet material which has a substantial amount of strength and toughness in excess of that of conventionally creped sheets produced at a comparable moisture content, which process comprises passing a substantially dry web of a sheet material having a moisture content below about 15% through a nip formed by a hard roll and an elastic roll having a Shore durometer hardness of from 10° to 45°, said hard roll being driven at a surface speed greater than the speed of said elastic roll, and compressively creping said web in said nip while simultaneously causing one side thereof to be smoother than the other side without disturbing the creped texture on the said other side.

8. The process of claim 4 wherein the hard roll is driven at a surface speed above about 5% greater than the speed of the elastic roll.

9. A dry-creped sheet produced by the process of claim 1.

10. A dry-creped paper sheet produced by the process of claim 4.

11. A process of making a laminated, stretchable, multi-ply, non-woven sheet material which comprises simultaneously passing a plurality of webs of such material in one general direction and bringing them together in face-to-face relationship in a creping zone, at such creping zone subjecting said webs to an elastic mass moving in said direction in engagement with an outermost web while simultaneously moving and pressing said webs against a substantially hard surface moving in the same direction as said mass but at a greater speed to compressively form crepe folds on each of said plurality of webs which simultaneously interlock and thus secure said webs together.

12. A process of making a laminated, stretchable, multi-ply sheet of material including paper in the substantially dry state wherein complete inter-fiber bonding of the cellulosic fibers of said paper has occurred, which comprises passing a plurality of webs of such material including the paper in said inter-fiber bonded state through a nip formed by a rotatable hard roll and an elastic roll with the hard roll driven at a surface speed greater than the speed of the elastic roll, and compressively creping said webs together in said nip by formation of successive crepe folds on each of said plurality of webs which simultaneously interlock and thus secure said webs together.

13. A process of making a laminated, stretchable, multi-ply sheet of material including paper in the substantially dry state wherein complete inter-fiber bonding of the cellulosic fibers of said paper has occurred, which comprises passing a plurality of webs of such material including the paper in said inter-fiber bonded state through a nip formed by a rotatable hard roll and an elastic roll with the hard roll driven at a surface speed greater than the speed of the elastic roll, compressively creping said webs together in said nip by formation of successive crepe folds on each of said plurality of webs which simultaneously interlock and thus secure said webs together; and prior to such creping dampening at least one of said webs below a total of about 15% moisture content without affecting the inter-fiber cellulosic bond of the paper, to facilitate creping of the webs.

14. A dry-creped metal foil sheet produced by the process of claim 1.

15. A dry-creped plastic sheet produced by the process of claim 1.

16. A dry-creped nylon sheet produced by the process of claim 1.

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