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(54) **EXPANSION APPARATUS AND METHOD
FOR PRODUCING INTERLOCKING
EXPANDED SLIT SHEET PACKAGING
MATERIAL**

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(57) **ABSTRACT**

A paper product comprised of two or more slit material layers, each layer having a pattern design to create interlocking layers of expansion sheet packaging materials. Each layer expands to create a three dimensional open netting of cells of hexagons, and the like, and is designed to have limited nesting with its opposing layer, thereby maximizing the thickness of the combined layers as compared to nested layers. The layers having differing slit patterns that produce when expanded, inclined land areas that having different angles of inclination of the land areas, such that adjacent layers can interlock, that is, have a restricted amount of nesting.

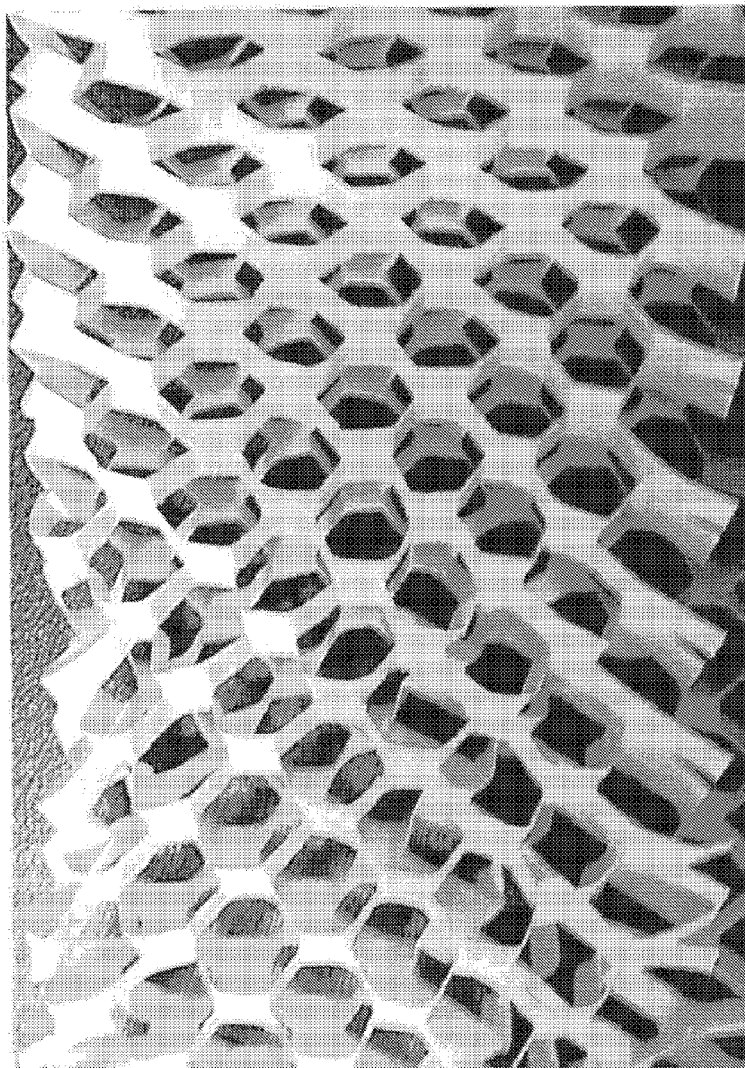


FIG 8

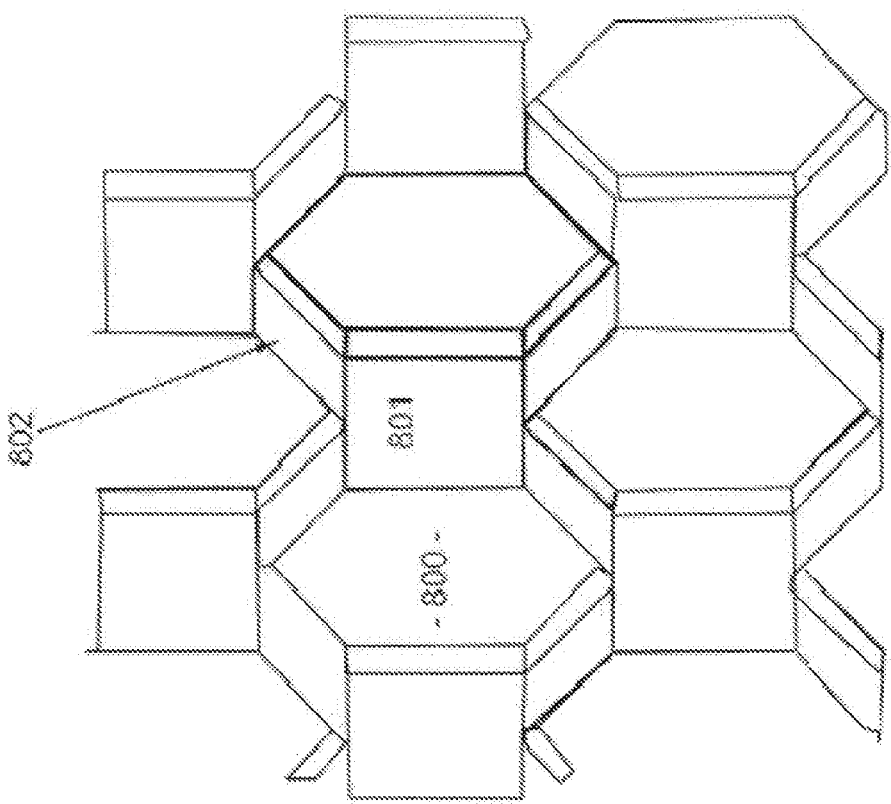


FIG 1

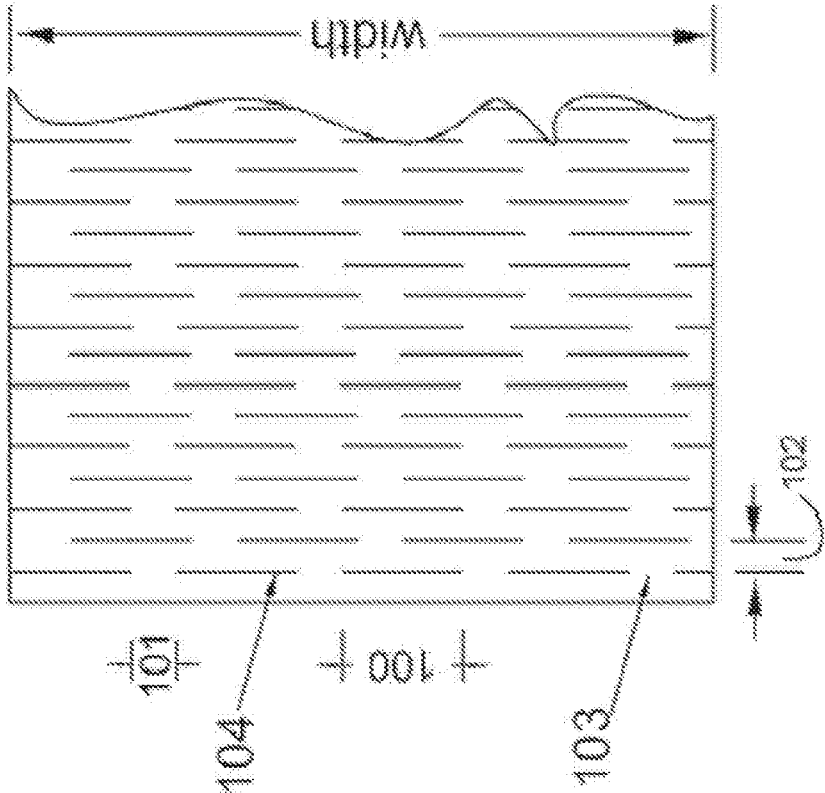


FIG 2 Prior art

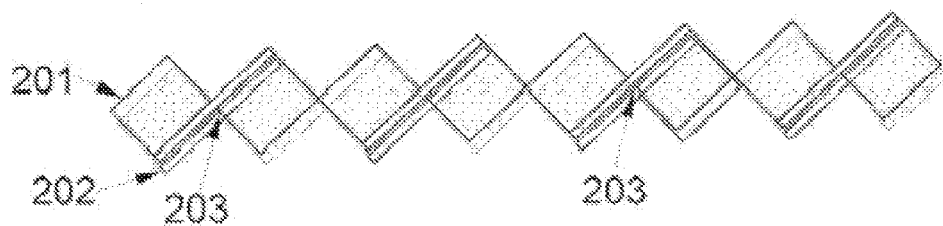


FIG 3 Prior art

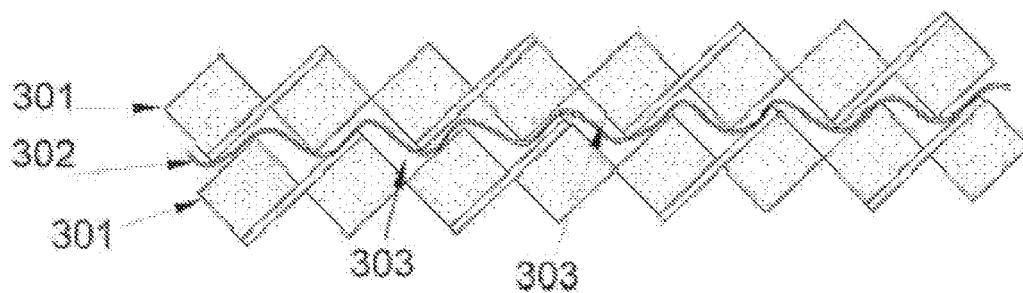


FIG 4

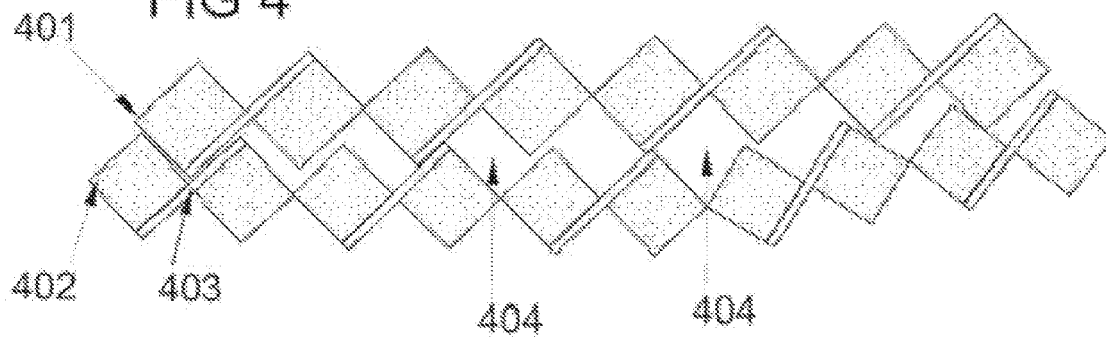
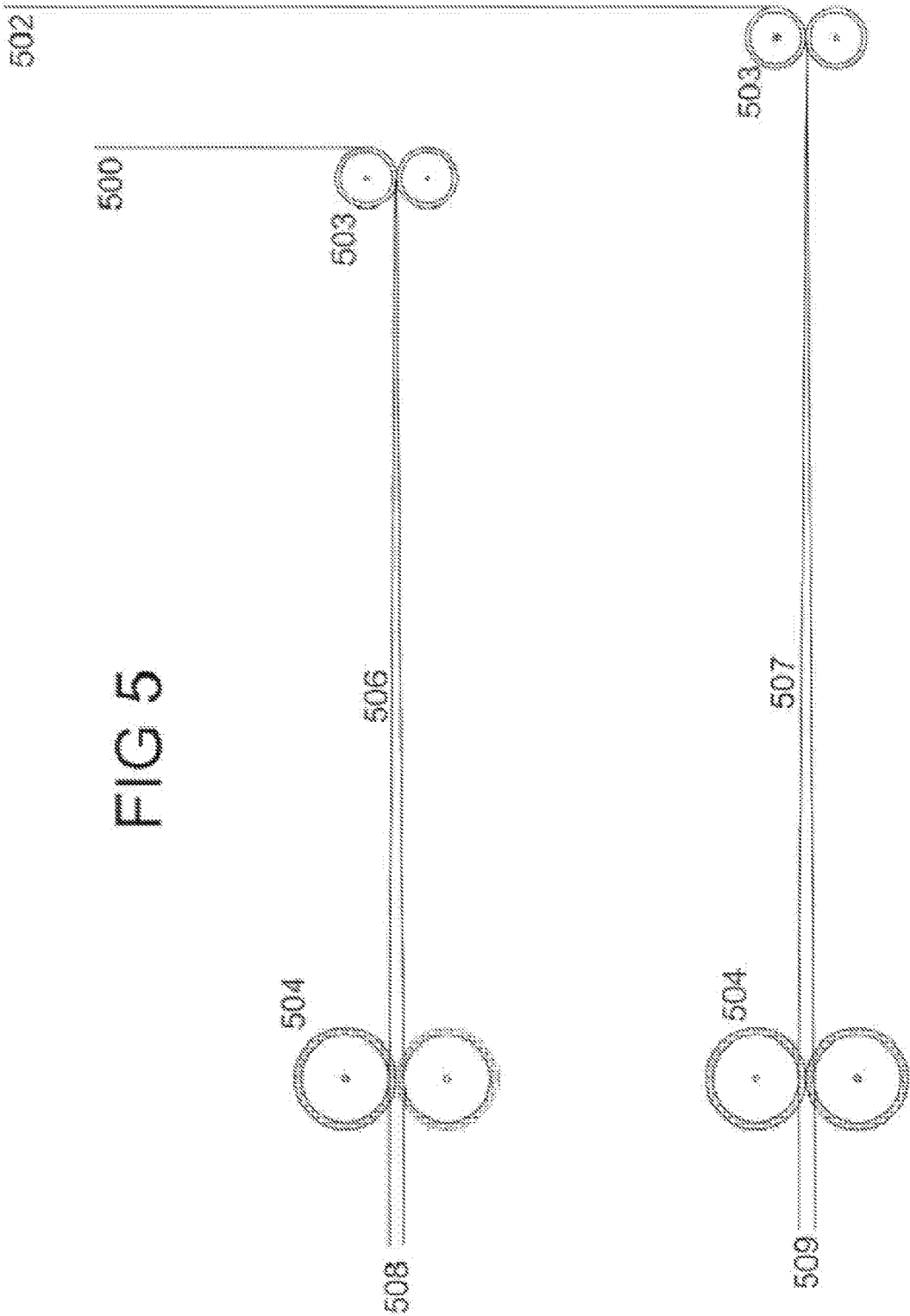
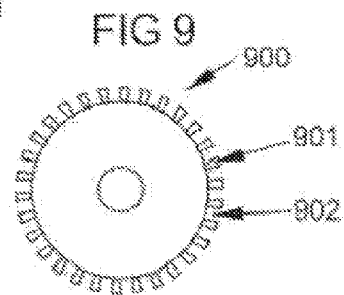
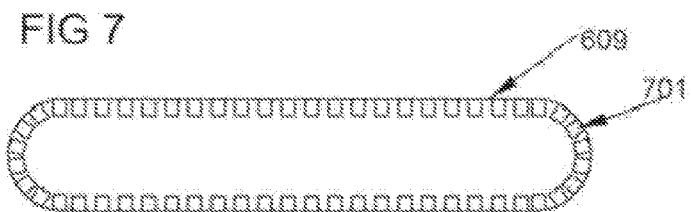
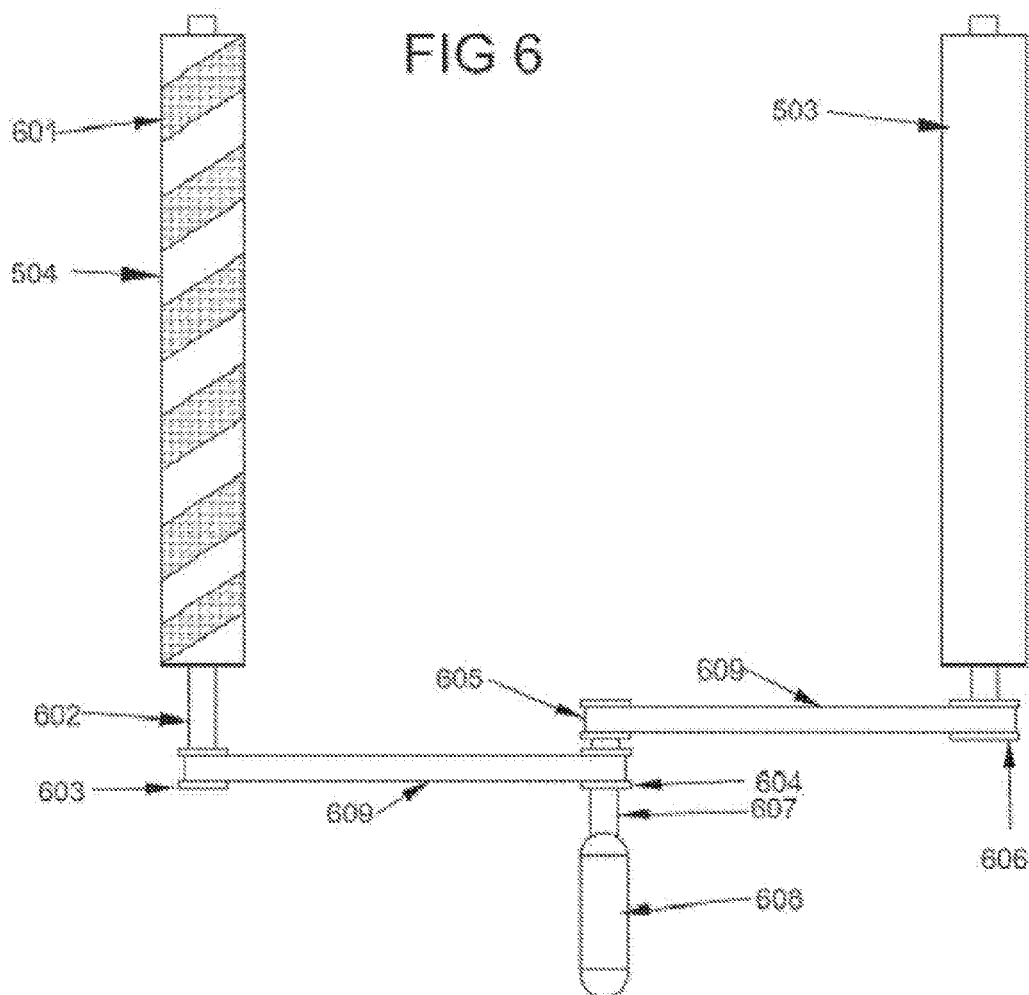


FIG 5





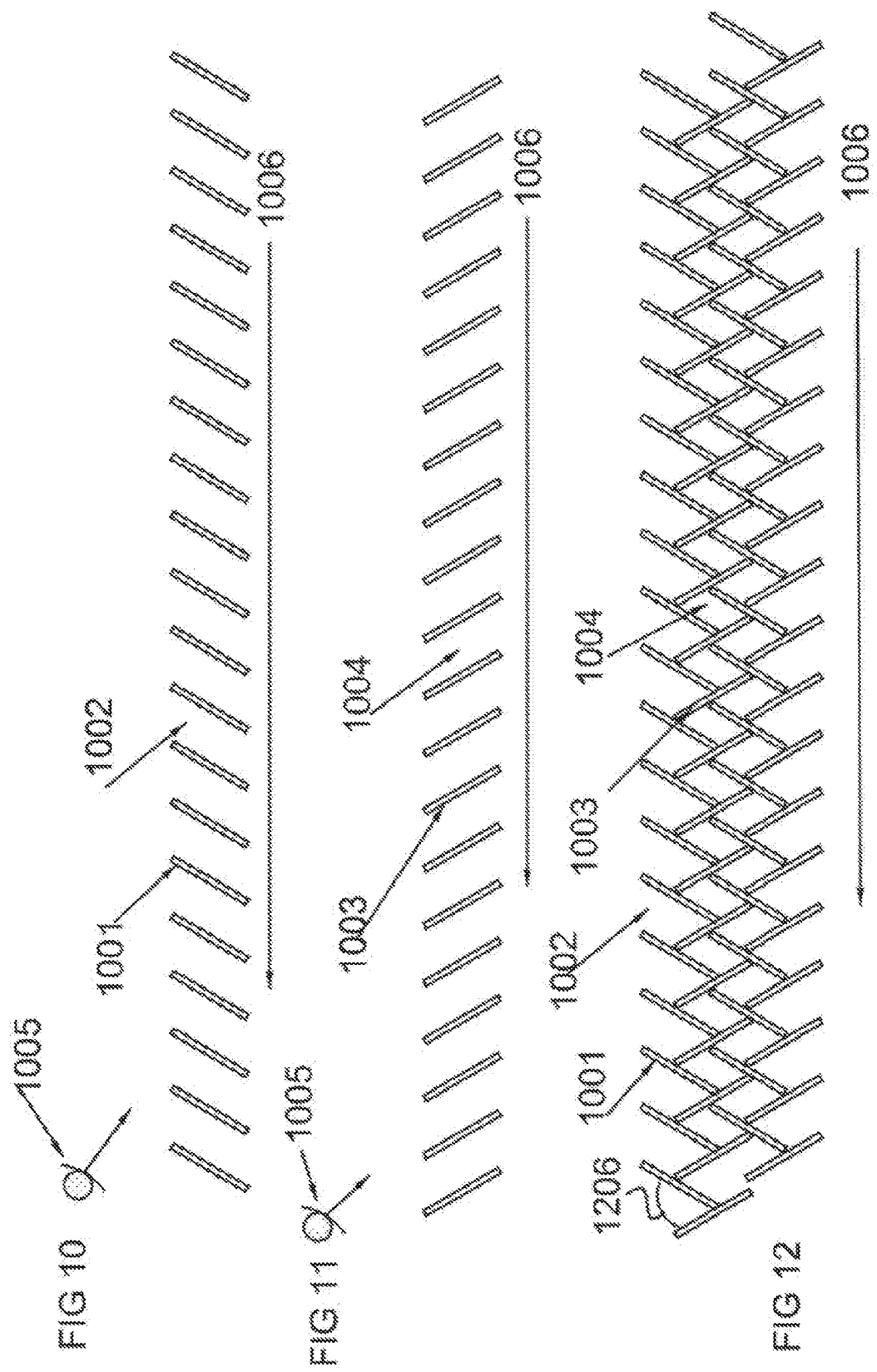


FIG. 13

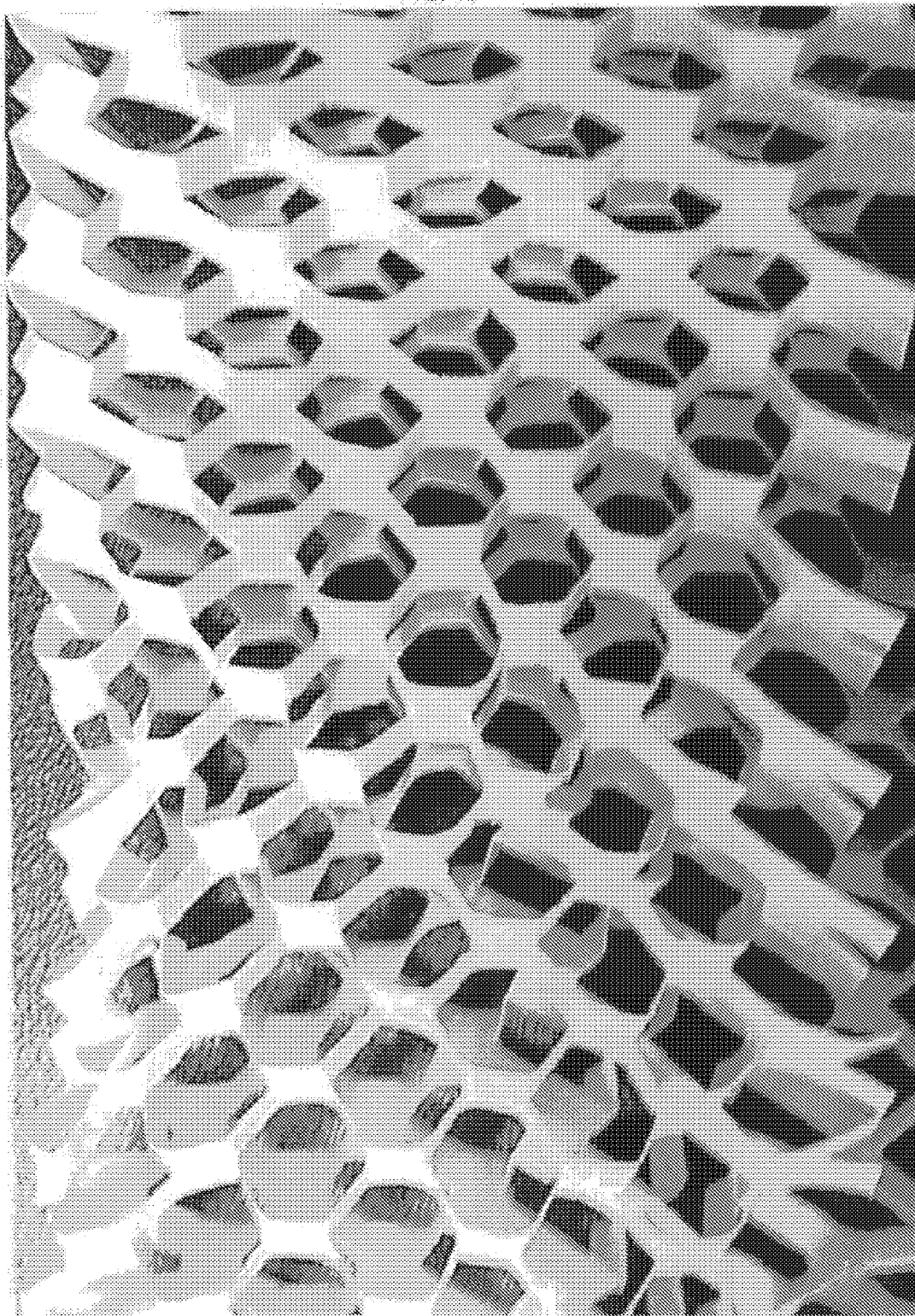
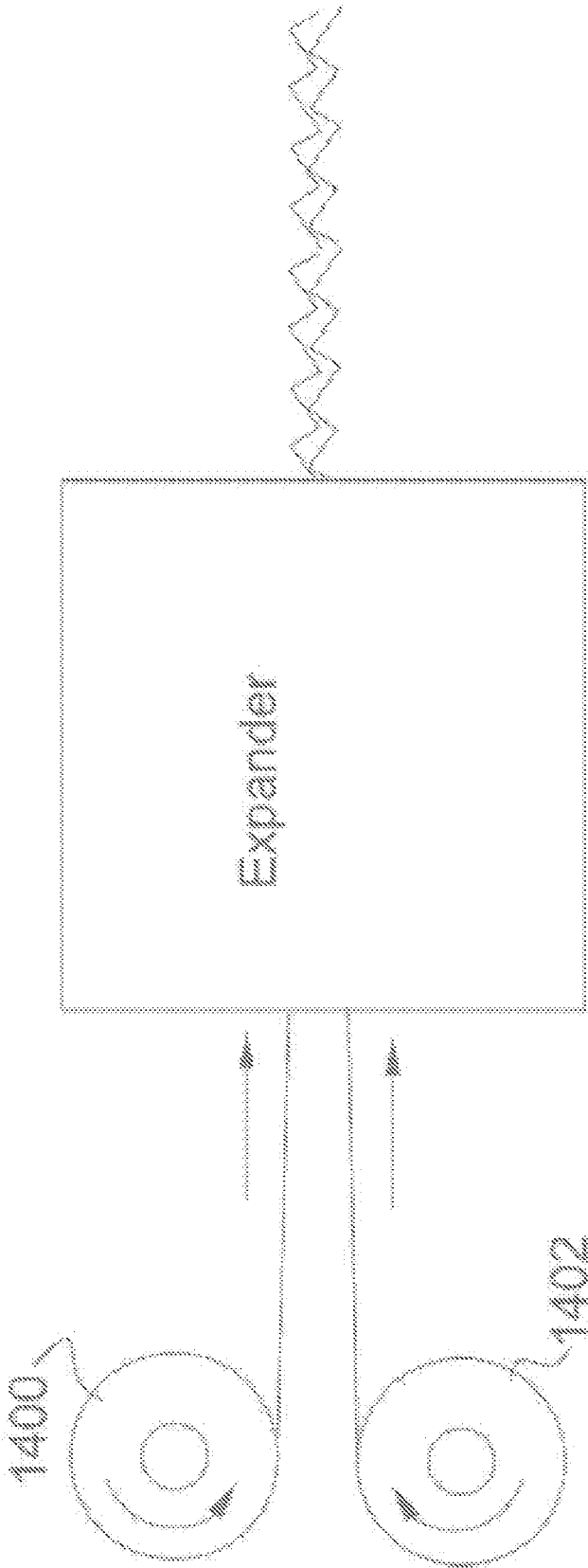
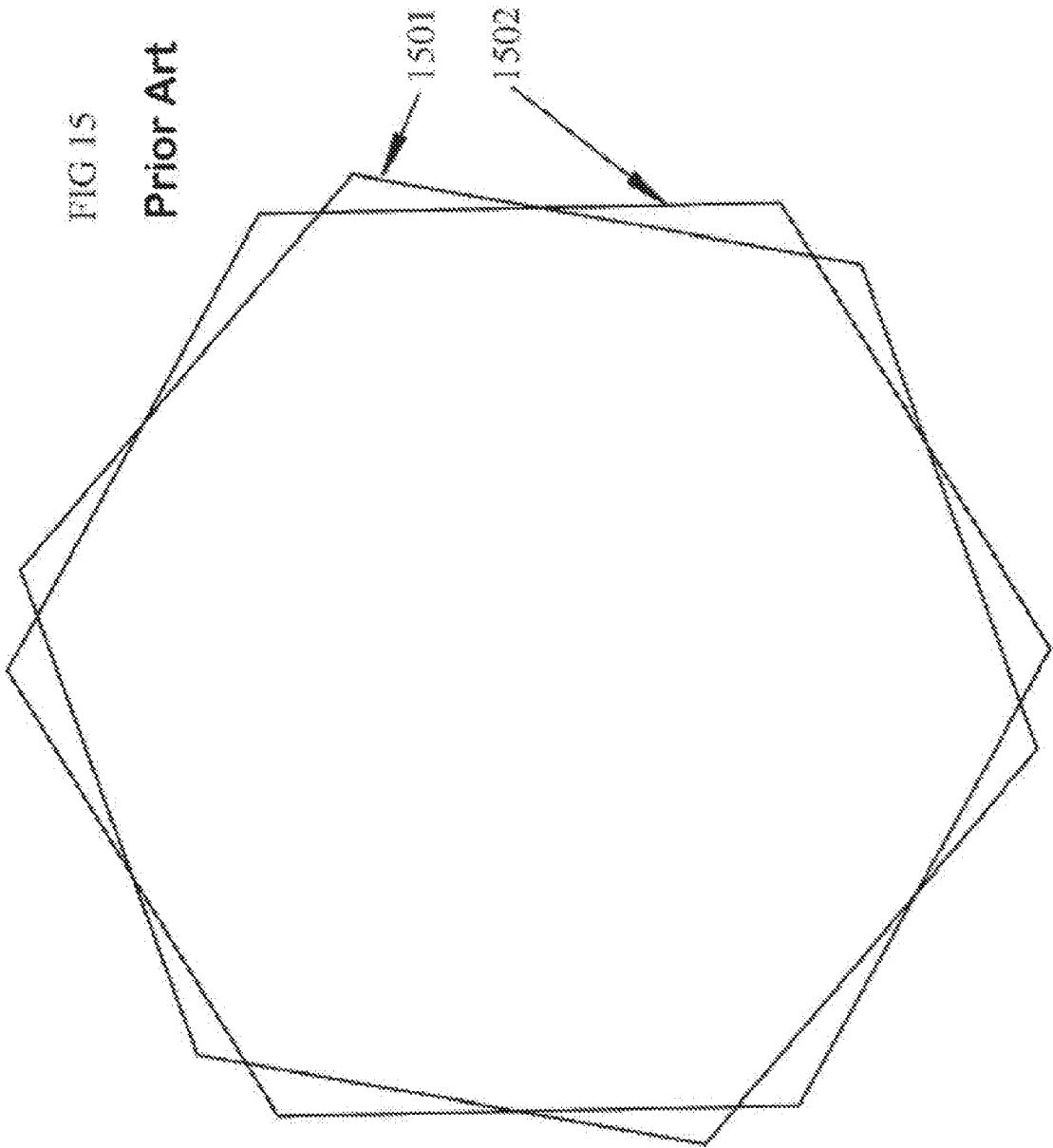
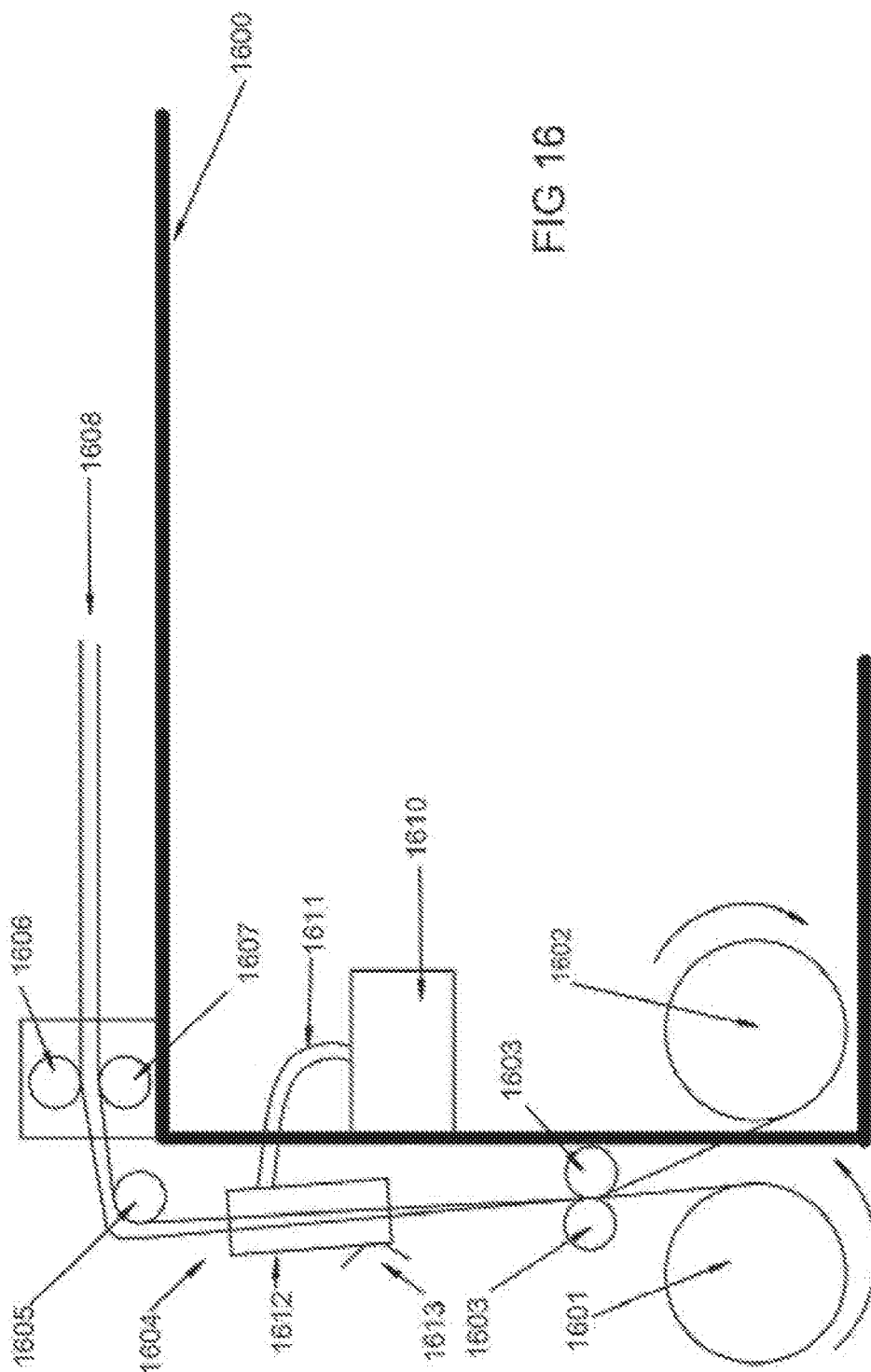
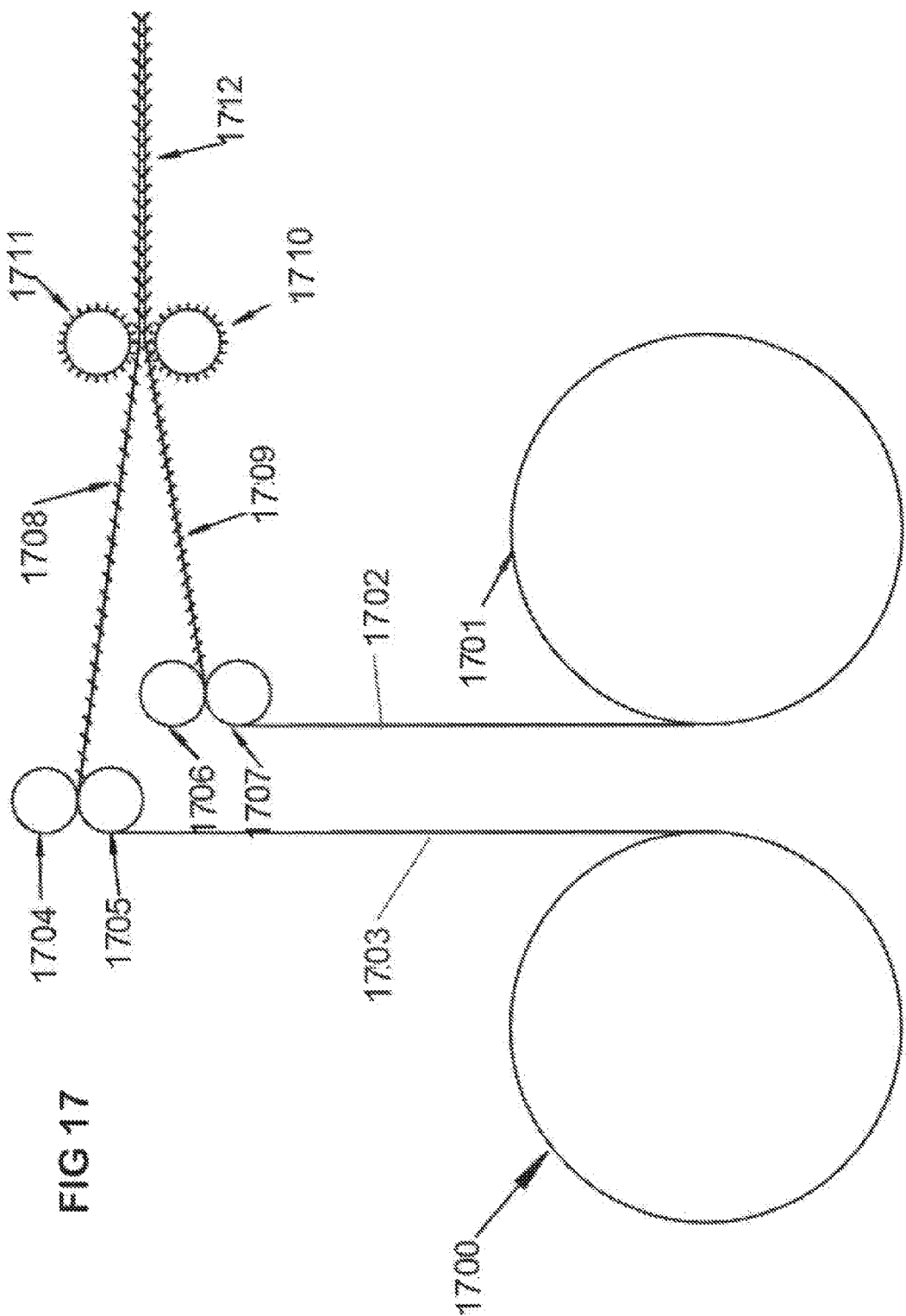


FIG. 14









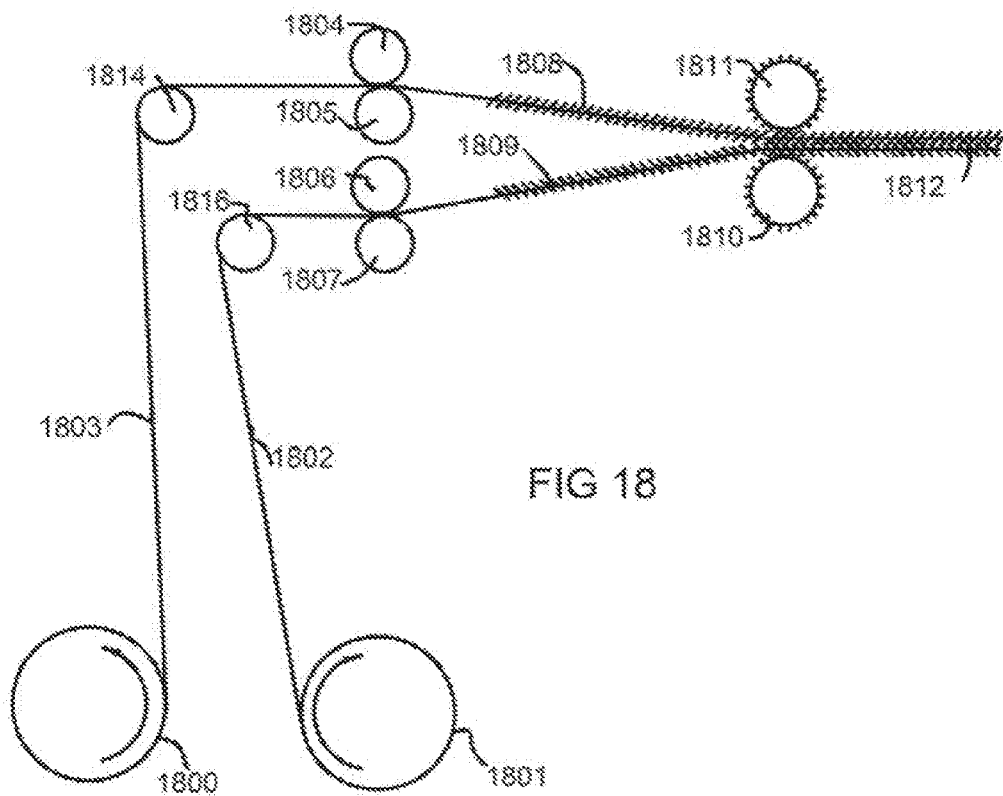


FIG 18

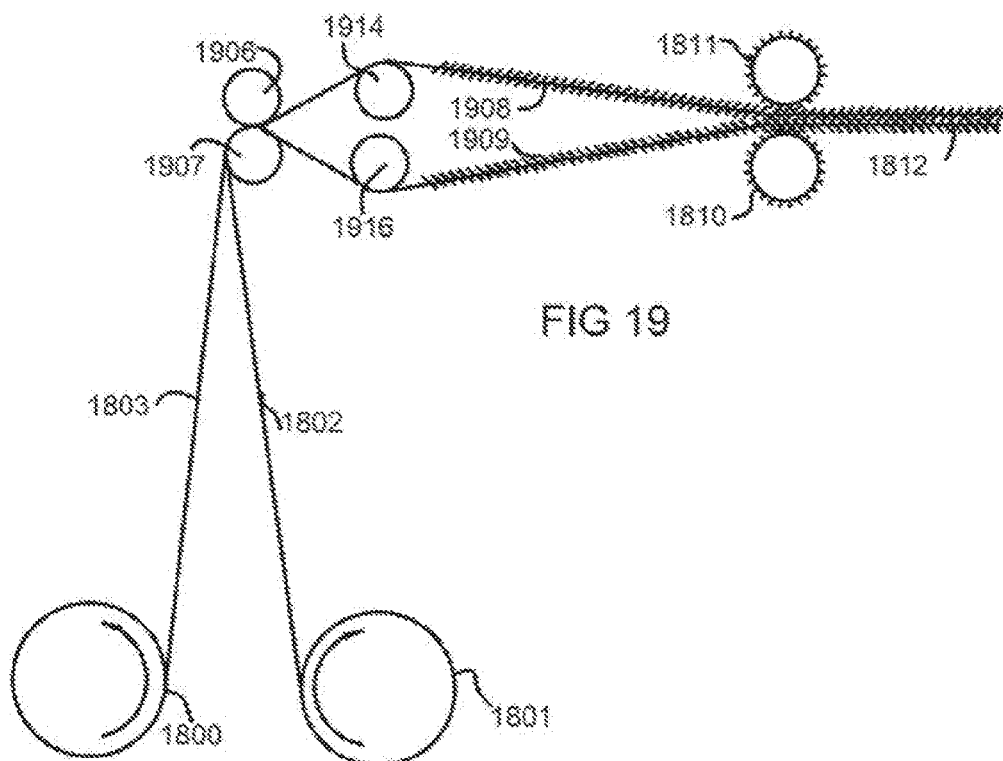
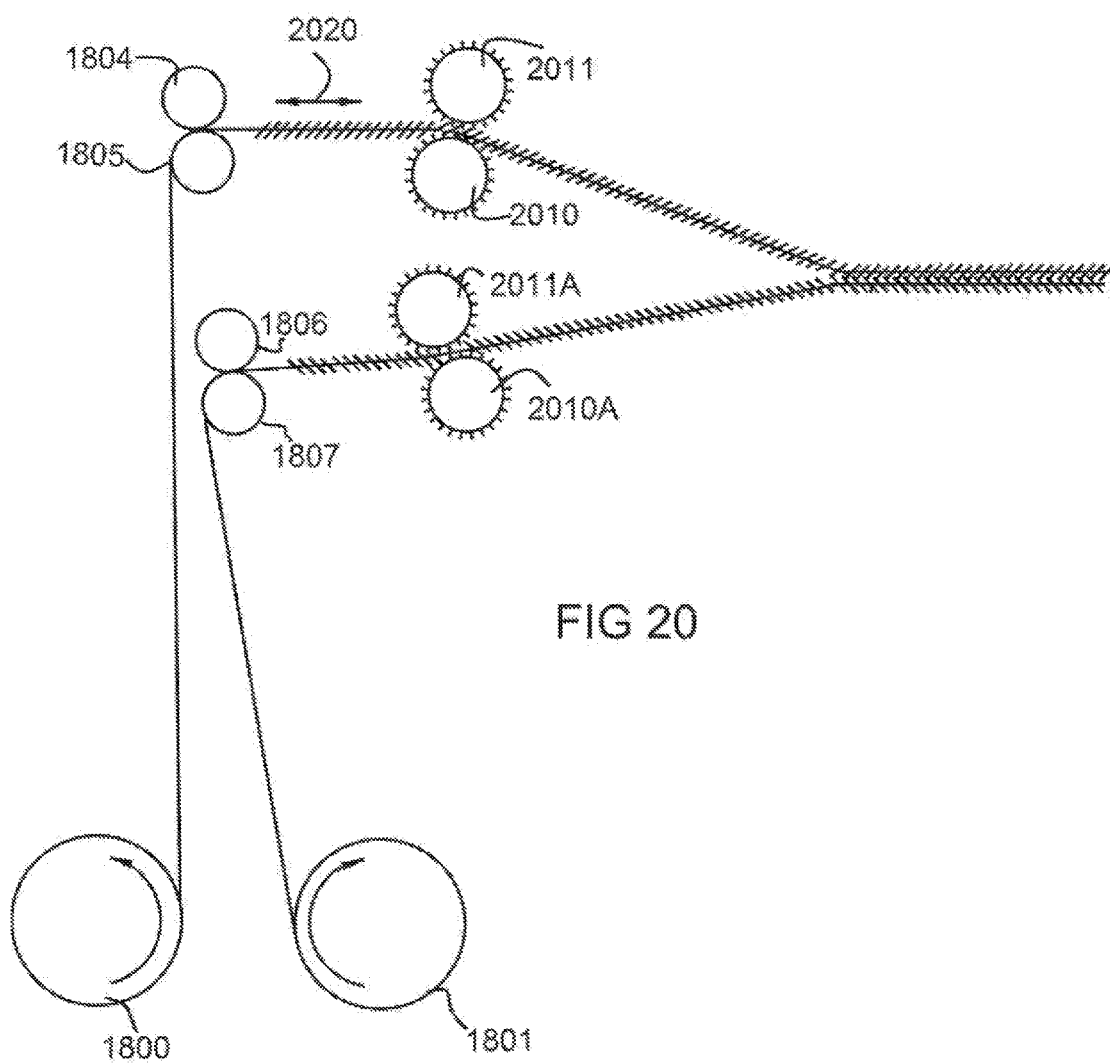


FIG 19



EXPANSION APPARATUS AND METHOD FOR PRODUCING INTERLOCKING EXPANDED SLIT SHEET PACKAGING MATERIAL

FIELD OF THE INVENTION

[0001] This invention relates to an expander for a paper packaging material that is slit, expanded and layered around an object or used as a void fill.

DESCRIPTION OF THE PRIOR ART

[0002] There are a small number of in-the-box wrapping products found in the market today used to fill the open area within a box that is unused by the item being shipped. Wrapping an item to be shipped puts a barrier between it and the box. It also creates a larger cubic area as it sits within an adjacent void-fill product such as Styrofoam peanuts. The larger cubic area cushions as well as inhibits migration of the item to the sides of the package.

[0003] Pleated Paper of U.S. Pat. No. 6,871,480 teaches using pleated paper laminated or layered on one or more layers of tissue paper as a cushioning product. The pleat height, paper fiber length, and number of pleats per foot, provide a cushioning product that crushes as force is applied. This application teaches the use of pleated paper as a wrapping material.

[0004] Bubble wrap®, well known in the art, can be obtained with ½ to 1" tall bubbles for the use as a wrap and void fill. It is capable of very good cushioning if made from a copolymer that is not recyclable or is very difficult to recycle. Homeowners are not able to recycle this type of plastic easily.

[0005] U.S. Pat Nos. 5,667,871 and 5,688,578, slit Sheet Packing Material, teaches the use of a plurality of individual slits forming parallel spaced rows forming a hexagonal expanded sheet with and without a separator sheet. It requires machinery to stretch the paper into its three dimensional shape at the customer's location such as disclosed in U.S. Pat. No. 5,538,778 which teaches the method and apparatus for producing the expansion of the slit sheet material performed at the packing site's location. This material is effective when used in conjunction with the separator sheet but, the separator sheet does not add to the thickness of the material. U.S. Pat. No. 5,782,735 discloses an expander for expanding the slit sheet material of U.S. Pat. Nos. 5,667,871 and 5,688,578.

[0006] The disclosures of U.S. Pat. Nos. 5,538,778, 5,667,871, 5,688,578, 5,782,735 and 6,871,480 are incorporated herein by reference, as though recited in full.

[0007] The prior art also teaches the use of offsetting the cells by having a slit pattern that relates the cells between 1 and 6 degrees to the right while the layer underneath has a slit pattern that rotates the cells between 1 and 6 degrees to the left. This cell offset in theory would inhibit the cells from nesting. Unfortunately the cell walls are flexible enough to allow for a plurality of the cells to nest thus negating the offset pattern. This failure to inhibit cell nesting was overcome with the tissue paper as described in prior art U.S. Pat No. 6,871,480.

SUMMARY OF THE INVENTION

[0008] A main object of the present invention is to overcome the shortcomings of the prior art.

[0009] In accordance with a broad embodiment of the invention, a novel paper product is comprised of two or more slit sheet packing material layers, each a layer having slit pattern designed to create interlocking layers of expansion sheet packaging materials. Each layer expands to create a three dimensional open netting of cells of hexagons, and the like, and is designed to have limited nesting with its opposing layer, thereby maximizing the thickness of the combined layers as compared to nested layers.

[0010] In accordance with a broad embodiment of the invention, adjacent layers have differing slit patterns and can be expanded through expander type machinery such that the expansion rates of the differing slit pattern layers can be varied to deliver the same width of exiting expanded material from each layer. Preferably the differing slit patterns produce when expanded inclined land area that have the same number of rows per inch, but different angles of inclination of the land areas, such that adjacent layers can interlock, that is, have a restricted amount of nesting.

[0011] In accordance with a broad embodiment of the invention, adjacent layers have differing slit patterns and can be expanded through expander type machinery such that the expansion rates of the differing slit pattern layers can be varied to deliver the same width of exiting expanded material from each layer. Preferably the differing slit patterns produce when expanded, inclined land areas that have about the same number of rows per inch, but different angles of inclination of the land areas, such that adjacent layers can interlock, that is, have a restricted amount of nesting and where the angle of inclination of the first layer is in the range from 50° to 85° and the angle of inclination of the second layer is in the range from 130° to 95°. Preferably, the angle of inclination of the first layer is in the range from 55° to 75° and optimally in the range from 55° to 65°. Preferably, the angle of inclination of the second layer is in the range from 125° to 105° and optimally in the range from 125° to 115°.

[0012] In accordance with another embodiment of the invention, adjacent layers have substantially the same slit patterns the produce sheets which when expanded the first layer has lands that are at an angle in the range from 50° to 85° and the angle of inclination of the second layer is in the range from 130° to 95°. Preferably, the angle of inclination of the first layer is in the range from 55° to 75° and optimally in the range from 55° to 65°. Preferably, the angle of inclination of the second layer is in the range from 125° to 105° and optimally in the range from 125° to 115°. It should be noted that the angle of inclination of the second layer is a mirror image of the angle of inclination of the first layer, thus, if the first layer has an angle of inclination of 60°, the second layer has an angle of inclination of 120°. In this embodiment, the sum of the angles of inclination of the first and second sheet is 180°.

[0013] In accordance with another embodiment of the invention, sheets of paper or plastic are slit in a pattern, that upon expansion, form an expanded slit sheet as described in U.S. Pat. No. 5,538,778, (see for example, FIGS. 1 and 2), and U.S. Pat No. 5,782,735 (see for example, FIGS. 19 and 20). The slit sheets are formed into rolls. A first roll is unrolled clockwise and expanded and a second roll is unrolled counterclockwise and expanded. Preferably, the two rolls are expanded simultaneously in an expander device which produces two adjacent layers of interlocking expanded sheets having cells, wherein the cells have land areas that are inclined relative to unexpanded sheets, and

wherein the angle of inclination of one of the adjacent expanded sheets is the mirror image of the angle of inclination of the other expanded sheet. The expanded, interlocking sheets are wrapped around an object, to form at least four layers of expanded sheet material, that is, two winding of the double layers of expanded sheet material.

[0014] In accordance with another embodiment of the invention, one or more layers of slit sheet material can be made from a paper comprising a soft paper such as paper towel type material so that it is soft on the hands while manually manipulating the packaging material around items being packaged. Preferably, one layer is of Kraft paper, and the adjacent layer is of a paper towel material.

[0015] In accordance with another aspect of the invention, expanded slit sheets are layered such that adjacent sheets consistently have lands with angles of inclination that are substantially reversed from each other, and interlock over substantially the entire length of the sheets and preferably, over the entire length of the sheets, thereby producing an improved packing material as compared to prior art products. Preferably the angles of inclination one of the adjacent sheets is the mirror image of the angles of inclination of the lands of the other of the adjacent sheets.

[0016] In accordance with another aspect of the invention, an expander is employed that has two sets of pinch rollers, one for each slit sheet. The use of two sets of pinch rollers enables a separation between adjacent slit sheets to be provided between the sheets at the initial region of expansion. Once the cells are expanded the material does not reverse so it is only the very beginning of the expansion where this is vital for the cells to act based on the wedge effect of the tool as disclosed in co-pending applications 62/025,536, filed Jul. 17, 2014 and Ser. No. 14,480,319, filed Sep. 8, 2014, the disclosures of which are incorporated herein by reference, as though recited in full.

[0017] It has been discovered that there is an interference of expansion of two slit sheet materials passing through only one set of rear pinch rollers. This interference creates uniformly opened cells on both sheets soon that there is perfect nesting of the expanded cells. This happens even when the slit sheets are designed to be reversed with respect to each other. As the first sheet begins to expand it forces the cells of the second sheet in the direction of its expansion so that there can be perfect cell nesting. When the cells of one sheet reverse in direction (switches back), so does the adjacent sheet's cells. This creates what appear to be random cell openings but upon closer inspection shows that the sheets are reversing cell order in sections and maintaining the nesting that is adverse to the use of the slit sheets as a packaging product. It has now been found to the use of two sets of pinch rollers, one for each slit sheet, can provide for a separation between the expanding slit sheets at the initial region of expansion. Once the cells are expanded the material does not reverse and thus do not nest. Accordingly, it is only at the initial region of the expansion where it is vital for the cells to open as a result of the wedge effect of the tool as disclosed in co-pending application Ser. No. 14/480,319.

[0018] Providing for a separation between the expanding slit sheets at the initial region of expansion is preferably enabled by using two sets of pinch rollers, one for each slit sheet and maintaining a separation between the two slits sheets at the initial region of expansion. Once the cells are expanded the cells do not readily reverse so it is only the very beginning of the expansion where it is vital for the cells

to open based on the wedge effect of the tool as disclosed in co-pending application Ser. No. 14/480,319.

[0019] It has now been discovered that once the cells form a region of expanded material, the cells resist reversal and do not nest with an adjacent sheet of expanded material.

[0020] Accordingly, two slit sheets are maintained separated from each other at the initial region of the expansion where it is vital for the cells to open as a result of the wedge effect of the tool as disclosed in co-pending application Ser. No. 14/480,319. After the cells have expanded to an extent that is sufficient to resist reversal, the two slit sheets are positioned adjacent to each other in an interlocking relationship.

[0021] In an alternate embodiment, adjacent layers have differing slit patterns and can be expanded through expander type machinery such that the expansion rates of the differing slit pattern layers can be varied to deliver the same width of exiting expanded material from each layer. Preferably the differing slit patterns produce when expanded inclined land area that have the same number of rows per inch, but different angles of inclination of the land areas, such that adjacent layers can interlock, that is, have a restricted amount of nesting.

BRIEF DESCRIPTION OF DRAWINGS

[0022] The invention will be described with the accompanying drawings, in which:

[0023] FIG. 1 is a top view of one of the layers of unexpanded slit sheet paper material.

[0024] FIG. 2 is a side view of two identical expanded slit sheet paper materials as they nest in one another (Prior Art).

[0025] FIG. 3 is a side view of two identical expanded slit sheet paper materials with a separator sheet between the layers as they rest one on top of the other (Prior Art).

[0026] FIG. 4 is a side view of two differing expanded slit sheet paper materials placed one on top of the other.

[0027] FIG. 5 is a side view of the expander rolls section of an automatic expander.

[0028] FIG. 6 is a top view of the expander rolls within the internal workings of an automatic expander.

[0029] FIG. 7 is a side view of the belt used to rotate the expander rolls in conjunction with feed rolls.

[0030] FIG. 8 is a top perspective view of one layer of expanded sheet material.

[0031] FIG. 9 is the side perspective view of an example of one of the gear pulleys used to rotate the expander rolls.

[0032] FIG. 10 is a schematic illustration showing a backward orientation of the lead walls of the web.

[0033] FIG. 11 is a schematic illustration showing a forward orientation of the lead walls of the web.

[0034] FIG. 12 is a schematic illustration showing the combination of a backward orientation of the lead walls of an upper web, a forward orientation of the lead walls of an upper middle web, and a backward orientation of the lead walls of a lower middle web and a forward orientation of the lead walls of a lowermost web.

[0035] FIG. 13 is a photographic representation of the combination of a forward and rearward oriented layer of expanded slit sheet material.

[0036] FIG. 14 is a schematic representation of the rollers for feeding unexpanded slit sheet material to an expander.

[0037] FIG. 15 is a depiction of the prior art representation offset hexagonal cells that was designed to inhibit cell nesting.

[0038] FIG. 16 is a side view of the vertical expander that is designed to save space on a packing table.

[0039] FIG. 17 is a schematic representation of two rollers for feeding unexpanded slit sheet material to an expander having two pair of pinch rollers and a single pair of expansion rollers.

[0040] FIG. 18 is a schematic representation an alternate embodiment of two rollers for feeding unexpanded slit sheet material to an expander having two pair of pinch rollers and a single pair of expansion rollers, and illustrating the initial region of expansion.

[0041] FIG. 19 is a schematic representation of a further alternate embodiment of two rollers for feeding unexpanded slit sheet material to an expander having two pair of pinch rollers and a single pair of expansion rollers, and illustrating the initial region of expansion.

[0042] FIG. 20 is a schematic representation an alternate embodiment of two rollers for feeding unexpanded slit sheet material to an expander having two pair of pinch rollers and two pair of expansion rollers, and illustrating the initial region of expansion.

DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

Glossary of Terms

[0043] Where the definition of a term departs from the commonly used meaning of the term, the definitions provided below shall be used, unless specifically indicated otherwise.

[0044] For the purposes of the present invention, the term “slit sheet material” refers to the use of offset rows of slits that preferably form a hexagonal, three dimensional product that is flexible and can conform to the shape of an item needing wrapping.

[0045] For the purposes of the present invention, the term “cells” means the hollow three dimensional shapes that are created when the slit sheet material is expanded longitudinally. The longitudinal expansion causes a narrowing of width of the sheet material.

[0046] For the purposes of the present invention, the term “lead wall” means the part of the cell that is the full height of the hexagonal shape created from the expansion of the slit sheet material.

[0047] For the purposes of the present invention, the term “connecting wall” means the part of the cell that is half the height of the cell created from the expansion of the slit sheet material.

[0048] For the purposes of the present invention, the term “cell size” means the open space dimension created when expanding the slit sheet material.

[0049] For the purposes of the present invention, the term “slit row spacing” means the distance between the rows of slit and un-slit patterns within the slit sheet material.

[0050] For the purposes of the present invention, the term “Kraft paper” means the industry name of paper that is measured in weight for every three thousand square feet of material. Thus the weight of 50 # Kraft Paper would be the weight of 3000 square feet of paper.

[0051] For the purposes of the present invention, the term “basis weight” means the specification relating to paper that measures the weight of a certain square foot area of paper. Thus the basis weight of 3000 square feet of Kraft Paper

weighing 50 pounds equals a 50# basis weight. The basis weight of Tissue paper is based on 2,880 square feet.

[0052] For the purposes of the present invention, the term “recycled paper” means material that is substantially made from recycled paper in the 90% range or more and is paper that has been returned to the manufacturing process, having once or more been made into a paper product, and remade into a paper sheet.

[0053] For the purposes of the present invention, the term “paper fibers” are the individual component of paper that makes up a paper sheet.

[0054] For the purposes of the present invention, the term “Nesting” means the grouping of cells onto or into one other such that an upper slit sheet material cell can fit within the lower slit sheet material cell to the point at which the thickness gain is not substantial.

[0055] For the purposes of the present invention, the term “interlocking” means the grouping of cells onto or into one another is such that an upper slit sheet material cell can nest within the lower slit sheet material cell only to the point at which the average thickness gain of two layers is no less than 70% of the thickness of both layers of a two layer pair and preferably, no less than 80% of the thickness of both layers of a two layer pair. For example, if each layer is 0.5 inches thick, then the average thickness would be no less than 0.7 inches and preferably no less than 0.8 inches.

[0056] For the purposes of the present invention, the term “adjacent” means that two layers are immediately adjoining, that is, one layer overlays the other without intervening space and are touching. Layers that nest or interlock to any degree have no intervening layers, are accordingly, in contact with each other and therefore adjacent.

[0057] The term “pattern of cells of expanded sheets” means the cell shape configurations such as hexagonal or oval, and cell dimensions such as leg length or width. The term “pattern” means physical characteristics and dimensions and is not inclusive of decorative or ornamental features of the design of a pattern.

[0058] For the purposes of the present invention, the term “average thickness” is employed to indicate that since some nesting may be present in layers of sheet that are within the definition of “interlocking” as employed here, the thickness of two adjacent layers can vary. Average thickness is measured as the sum of the thickness measured at a plurality of linear intervals, divided by the number of intervals in the plurality of linear intervals. Thus, if thickness measurements are taken every inch over a length of two feet, then the sum of the measurements divided by 24 equals the average thickness.

[0059] For the purposes of the present invention, the term “interlocking” adjacent layers nesting to a limited extent that is sufficient to resist contraction of expanded sheets. p For the purposes of the present invention, the phrase “paper width after expansion” means the width of the sheet of paper after expansion of the slit paper sheet. The decrease of the width of the sheet of paper after expansion is referred to as “necking down”. The “percent of necking down” is the percent decrease in paper width after expansion. Thus, a 25 inch width sheet which necks down to 20 inches would be necked down 20%.

[0060] For the purposes of the present invention, the phrase “paper width differential” means the difference in width of two adjacent layers of slip paper sheets. Since different slit patterns will yield different amounts of necking

down, the paper width differential prior to the expansion step must be sufficient to yield little or no paper width differential after the expansion step. It should be understood that the sheets of expanded paper can be trimmed down to negate any paper width differential post expansion. However, this would constitute a waste of paper and require an additional step or steps, and accordingly, it is preferable to negate any paper width differential by determining a pre-expansion paper width differential that achieves, in combination with the slit patterns of each of two adjacent sheets, a substantially identical paper widths post expansion.

[0061] For the purposes of the present invention, the term "Operator" means the person that operates the machinery that automatically expands the slit sheet material that dispenses the product towards the operator.

[0062] For the purposes of the present invention, the term "about", means the numerical value, plus or minus 15%.

[0063] For the purposes of the present invention, the terms "substantially", and "approximately" mean the numerical value, plus or minus 5%.

[0064] For the purposes of the present invention, the terms "region of initiation of expansion" and "initial region of expansion" mean the region of expansion in which the slit sheets form cells that resist reversal such that when two layers are brought into contact with each other, the expanded slit sheets interlock rather than nest.

[0065] Slit Sheet Materials

[0066] For the purposes of the present invention the descriptions of the paper and slit patterns within the embodiment of U.S. Pat. No. 5,667,871 can be used within this application. The material can be as described in the '871 patent, except that the two differently sized slit patterns are employed in the present invention, rather than just the one pattern of the '871 patent. These two slit patterns substantially negate the nesting problem associated with the prior art patent U.S. Pat. No. 5,667,871.

[0067] Further information relating to the paper which can be used in the present invention, slit patterns, and the expansion process is found in U.S. Pat. Nos. 5,538,778, 5,667,871, 5,688,578, and 5,782,735, the disclosures of which are incorporated by reference herein, as though recited in full.

[0068] Each slit pattern will require varying paper strength and thickness to perfect its crush strength and ease of stretching within the automated expander.

[0069] The slit pattern dimensions set forth below are one example of the composite products from the two or more varying slit sheet materials. There are a number of slit sheet variations that will work to inhibit nesting and the specific dimensions and shapes created below should not limit the patterns that can be used to make the new art. The critical feature is that the slit patterns of adjacent layers differ in slit length, spacing between slits in a row, and/or the spacing between rows of slits.

[0070] The paper used to manufacture the slit sheet material is preferred to be recycled and is in the range of 40-80 pounds in basis weight dependent upon the cell size of the slit sheet expanded material. It is preferred to use the slit pattern that is approximately three-to-one in size between the length of the slit portion and the un-slit portion of the slit sheet material. In this instance a $\frac{1}{2}$ " slit portion followed by a $\frac{3}{16}$ " un-slit portion is a preferred pattern in the first row. Each row is $\frac{1}{8}$ " apart and bisects or is transverse to the direction of manufacturing the slit sheet material. Each slit

pattern row below is offset to the above pattern such that the slit portion bisects the unslit pattern of the upper row and so forth. This alternating pattern enables the paper to be expanded in to the web of hexagonal, diamond, square, or round shaped three dimensional cells that are created dependent upon the specific slit pattern. A hexagonal pattern is created with the approximate three-to-one slit to unslit lengths. It has been established that the hexagonal shape is the strongest of all the cell shapes and therefore is the preferred embodiment to the new art. There are exceptions when a softer cushioning material is required where one of the slit sheet materials is a hexagonal layer with the adjoining layer slit sheet designed to be a square. In this instance the preferred embodiment is for both layers to substantially create hexagonal cells.

[0071] The second layer of slit sheet material retains the same three dimensional thickness as the first layer of slit sheet material. The thickness can be created from the spacing of the rows. In this instance the spacing is $\frac{1}{8}$ " thus creating $\frac{1}{4}$ " long cells. Because these cells can only rotate short of 90 degrees toward a vertical orientation, the total height is approximately $\frac{3}{16}$ " overall. The lead wall of the cell is the portion of the cell that makes up the full depth of the slit sheet when expanded. There are two lead walls created no matter what shape the cells create or a slit pattern used. These two lead walls face the direction of manufacture and the surface area is made up of the un-slit area within the row and the space between the rows times 2. The depth of the lead wall can also be described as the un-slit space between every other set of rows or between the first and third rows.

[0072] The overall height of the expanded slit sheet material can also be described as a series of rows such that the first row of slits at position "0" is followed by its offset un-slit portion of the row underneath at position $\frac{1}{8}$ " below and not until the third row appears and the offset again places a slit at position $\frac{1}{4}$ ", thereby creating a total height of $\frac{1}{4}$ " for the lead walls of the hexagonal cell.

EXAMPLES

[0073] The first slit sheet pattern creates a $\frac{1}{4}$ " tall lead wall with each hexagonal side approximately being $\frac{3}{16}$ " long. The second slit sheet pattern is also $\frac{1}{4}$ " tall by using the $\frac{1}{8}$ " row spacing. The legs of the cell are approximately 10-30% less or more to create an interlocking composite product. In this case the preferred size would be 4" slit $\times$ 0.15" un-slit creating a cell that will be 20% smaller than the first slit sheet pattern.

[0074] The second expanded slit sheet pattern creates a cell that easily could fit inside the first expanded slit sheet material but is inhibited by the increase in quantity of the smaller cell size causing a miss-match of cells trying to fit within each other.

[0075] In order for the operator to receive both slit sheet expanded materials at the same speed a special expander is required. The first expanded sheet layer expands from 1" to approximately $2\frac{1}{8}$ " inches depending upon paper strength and thickness. In the present invention the 60 pound basis weight paper expands to the $2\frac{1}{8}$ " inches for the $\frac{1}{2}$ " $\times$ $\frac{3}{16}$ " first slit sheet layer. This is an approximately 213% increase in the length of the slit sheet material and the expander will need create this exact expansion property for the first layer.

[0076] The second layer will be twenty percent smaller in size and therefore will expand 193% in length. Therefore the

second expansion rollers within the expander machinery will have a reduced expansion ratio to accommodate this smaller amount of expansion. This reduced expansion ratio would therefore automatically reduce the smaller secondary web layer speed exiting from the expander. To maintain the same exiting speed for both layers the back rollers that set the overall exit speed will have to be adjusted to 20% faster for the second layer.

[0077] Additionally, slight variations in cell size, of 5-10%, can be opened with the same expansion to rubber pinch roller ratio as the larger cell size due to the slipping effect of the expansion rollers. As the cell size grows the effect is minimized and either a larger cell is not opened fully for maximum benefit or a small cell shows tears or complete tearing of the slit sheet material.

[0078] With only a slight cell size variation, the paper width does not have to be exact such that if one web is slightly wider by no more than 5-10% then the efficiency of wrapping is maintained. This would make the loading of the expander easier as the upper web could be the lower web and visa-versa and the only difference would be the cell size on the upper web may change from smaller to larger or visa-versa.

[0079] Expander

[0080] The concept of the expander is to continuously feed the slit sheet layers to the operator and simultaneously expand those layers for ease of use. Otherwise the operator would have to manually pull the layers on a repeating basis as more flat layers of slit sheet material are delivered. To facilitate the two rolls about 10" apart or more from the front to the back of the machine operate at different speeds. A separate set of rubber coated feed rollers drive the first slit sheet material into the expander.

[0081] It has now been found that the employment of two sets of pinch rollers, one for each slit sheet enable a separation to be provided between the slit sheets at the initial region of expansion. Once the region in which cells are expanded is sufficient for the cells to resist reversing adjacent layers of expanded sheets interlock rather than nest, the layers are brought into contact, in an adjacent relationship. To enable formation of interlocking cells, the slit sheets are maintained separate at the region of initiation of the expansion. The cells thus are enabled to open based on the wedge effect of the sitting tool as disclosed in co-pending application Ser. No. 14/480,319 without interference from an adjacent expanding slit sheet. By way of contrast, if the slit sheets open while in contact, they tend to open in a nested configuration, thereby negating the non-nesting aspect of the present invention.

[0082] Preferably only one pair of front expansion rollers is necessary to pull an expanded sheet(s) through the system. The expansion rollers are spaced such that the two expanded sheets can pass through without being crushed while being forced by the tines of the expansion rollers. The expansion rollers are covered with the hook component of a hook and loop product and the tines of the hook unit are employed in the present invention. This is only able to happen when the two sheets are expanded and is counterintuitive to one skilled within the art that expects the tines of the hook component to pull the slit sheets through when flat as well as when expanded. In the present invention the operator needs only to allow the flat sheet material to pass through the hook rollers and then pull the slit sheet open (expanded) which immediately enables the hook tines to grab the

material and automatically continue the expansion process. The concept of powering the rear rollers creates an issue of crushing. The reason is that when the user places the paper into the back/pinch rollers, the machine must push the paper to the expander rollers. If the tines of the hook components of the expander do not grab the flat sheet then the paper just accumulates within the machine. Therefore the tines of the opposing rollers must be close enough to grab a flat sheet of paper which crushes the expanded sheet. Alternatively, the expander roller can be automated to move from a close spacing at start-up to a spaced relationship after the initial startup.

[0083] Hook-and-loop fasteners, hook-and-pile fasteners, or touch fasteners (commonly known as Velcro®) consist of two components; typically, two lineal fabric strips (or, alternatively, round "dots" or squares) which are attached (e.g., sewn, adhered, etc.) to the opposing surfaces to be fastened. The first component features tiny hooks; the second features even smaller and "hairier" loops. The present invention employs the hook component of the hook and loop fastener.

[0084] This method noticeably creates taller less wrinkled cells than through the method of one layer through one set of hook rollers. The two slit sheet expanded layers flex and adjust as they pass through the single pair of hook rollers unlike one layer of expanded sheet material. This flexing inhibits the crushing effect.

[0085] Specifications for HexCel Double Pinch Roll Expander

[0086] The pinch rollers are made of aluminum and have a plastic covering that is completely pressed against its opposing roller. There are adjustments to apply pressure to the rollers so that the paper is grabbed firmly.

[0087] The distance between the plastic pinch rollers and the Hook rollers is between 8 and 12 inches. If the distance is greater it does not affect the integrity of the product but does not add any value. If it is too short then the material is not given enough distance to stretch prior to the driven Hook rollers which will cause the product to fail to open completely.

[0088] The Hook rollers require an opening between the rollers so that the slit sheet material is not crushed as it passes between the rollers. That dimension optimally is $\frac{3}{16}$ ", the dimension of the slit sheet expanded material, less the length of the tines that make up the Hook that grab the material as it revolves to move the slit sheet material forward. The tines vary in height but $\frac{1}{16}$ " or 0.0625" is typical.

[0089] Using two layers of opposing slit sheet material creates a doubling of the height that passes through the Hook rollers less the interlocking that creates a slight loss of height. This dimension is 0.375" less an approximate loss of 5% of the height or 0.35". Setting the Hook rollers a distance of 0.35" will enable the Hook tines from both the upper and lower roller to grab the slit sheet at its full distance of $\frac{1}{16}$ ". Depending on the level of recyclable fibers within the slit sheet material will depend on whether the rollers need to close further to create more driving friction. This decrease in dimension would be about $\frac{1}{16}$ " between the two rollers.

[0090] The use of one set of expansion rollers provides a higher reliability in regard to the quality of the expanded paper. The result is more buoyance due to less crushing.

[0091] Friction pinch rollers can provide controlled variable expansion, by dialing in tension to vary the degree of

expansion. Powering the rear/pinch roller results in the ratio being permanent unless a gear is changed. In accordance with the present invention, the pinch roller tension is adjusted with a screw on each side of the roller. Virgin paper needs more force, while recycled requires less. Thinner paper needs more force, while thicker paper need less. Thus, the machine has an ease of versatility that not provided by the powered rear roller system.

[0092] Alternative, the pinch rollers can be driven, that is motor powered by the motor drive of the expansion rollers. Modified gears or a variable gear speed transmission can control the relative speed of the expansion rollers and the pinch rollers.

[0093] Alternatively, two separate motors can be employed with one controlling the speed of the expansion rollers and the other controlling the speed of the pinch rollers. This enables the pinch rollers-expansion rollers to vary the degree of expansion.

[0094] To produce a void-fill product, the slit paper is expanded to a degree which breaks fiber, thus minimizing or eliminating the tendency of the expanded paper to retract.

[0095] To produce a wrap product, it is preferred that the expanded paper retain its tendency of to retract, thus optimizing the interlocking effect.

[0096] Specifications for HexCel Double Pinch Roll Expander

[0097] The pinch rollers are made of aluminum and have a plastic covering that is completely pressed against its opposing roller. There are adjustments to apply pressure to the rollers so that the paper is grabbed firmly.

[0098] The distance between the plastic pinch rollers and the Hook rollers is between 8 and 12 inches. If the distance is greater it does not affect the integrity of the product nor add any value. If it is too short then the material is not given enough distance to stretch prior to the driven Hook rollers which will cause the product not to open completely.

[0099] The Hook rollers require an opening between the rollers so that the slit sheet material is not crushed at it passes between the rollers. That dimension optimally is $\frac{3}{16}$ ", the dimension of the slit sheet expanded material, less the length of the tines that make up the Hook that grab the material as it revolves to move the slit sheet material forward. The tines vary in height but $\frac{1}{16}$ " or 0.0625" is typical.

[0100] Using two layers of opposing slit sheet material creates a doubling of the height that passes through the Hook rollers less the interlocking that creates a slight loss of height. This dimension is 0.375" less an approximate loss of 5% of the height or 0.35". Setting the Hook rollers a distance of 0.35" will enable the Hook tines from both the upper and lower roller to grab the slit sheet at its full distance of $\frac{1}{16}$ ". Depending on the level of recyclable fibers within the slit sheet material will depend on whether the rollers need to close further to create more driving friction. This decrease in dimension would be about $\frac{1}{16}$ " between the two rollers.

[0101] Optionally, the rubber coated rollers (pinch rollers) can be restricted in speed by friction with just the expansion rollers being powered. Alternatively, they can be powered or gear connected to the powered expansion rollers. The friction would be adjusted to provide the ratio in speeds between the rubber rollers and the expansion rollers to provide expansion of the slit sheet material. The second set of expander rollers at the front of the machine are coated with the hook component of a hook and loop fastening device such as sold under the trademark "Velcro". The tines of the

hook component grab the slits, and drive the slit sheet to its expanded configuration by operating about 213% faster than the back rollers. The second slit sheet material will feed into an additional set of feed rollers and expander rollers that will set the ratio of 193%. In addition, the back rollers as well as the front rollers will operate 20-40% faster than the first set of rollers for the first slit sheet material. The design of the drive system shown in FIG. 6, 7, and 9 are with the use of a timing belt and corresponding gear pulley design. This does not preclude the design of typical flat or no-teeth belt designs which provide can slip when under load.

[0102] In an alternate design of the expander, as illustrated in FIG. 16, there is a separation of the expansion rollers 1606 and 1607, and the rubber rollers (pinch rollers) 1601 and 1602, such that the rubber rollers are behind the packing station and the expansion area is created vertically. This leaves just the expansion rollers sitting on top and at the extreme rear side of the packing table to reduce overall space that the expander would take up. It also reduces the foot print of the expander to just the width of the Expansion rollers and it associated housing and motor drive.

[0103] Soft Paper

[0104] The slit sheet material can be made from a variety of papers including Kraft Papers, recycled and virgin papers and the like. These papers when expanded form sharp edges that are sharp to the operator's hands and cause cuts to the skin. In most instances the operators where gloves when using slit sheet expanded paper materials. The new art as described below reduces or eliminates the sharp edges to the paper by utilizing a different type of paper yet used in the manufacture of slit sheet paper.

[0105] Paper manufactured such as prior art U.S. Pat. No. 5,061,344 for a "Method of making Soft Paper", is described as "Soft paper from cellulose fibers is manufactured by wet-forming a first fiber layer. Thereafter air-borne dry fibers are deposited directly on one or both sides of the wet-formed layer while this is still wet, so that a second and possibly a third fibre layer are formed on the first one. Fiber bindings thereby arise between the layers. The wet-formed fiber layer gives the soft paper its strength, while the dry-formed fibers give a soft surface. The disclosure of U.S. Pat. No. 5,061,344 is incorporated herein by reference as thought recited in full.

[0106] This is one design for making soft paper and can be utilized for expanded sheet material as it has good fiber strength and can be expanded into its three dimensional cell form. The use of this paper is within the range of 40-90# basis weight with the paper fibers running in the machine direction for food expansion strength. The soft paper thickness is thicker than typical Kraft paper thicknesses, as well known in the art, with soft paper thicknesses varying from 0.006"-0.012". The preferred basis weight for the soft paper is about 70, with a thickness of about 0.010".

Paper Making

[0107] The surface of paper can be glossy or matte, smooth, silky, rough, or something in between. The purpose of coating paper and making it glossy, i.e. calendaring, is to finish the paper's surface properties and to improve its printability. Different kinds of paper are needed for different applications. The final part of the paper making process is called finishing, which typically consists of the coating, calendaring, winding and roll handling phases. The first phase of finishing is the coating of the paper. The basic requirement for successful finishing is a high-quality base

paper, it is difficult to fix flaws in the base paper with coating. Paper can be coated on one side only or on both sides. Coating the paper several times often improves its printing properties. High-grade printing paper is coated up to three times.

[0108] After coating, the paper is calendered. A calender is a device with two or more rollers through which the paper is run. The compression of the rollers and the application of heat give the paper its smooth and glossy properties.

[0109] Uncalendered paper is porous and has an uneven surface. Moreover, the thickness of the paper fluctuates. Porosity and an uneven surface increase the consumption of printing ink and decrease printing quality. By calendering, or compressing the paper between rollers, the surface of the paper becomes suitable for printing machines. The higher the quality of the printing properties required, the smoother and glossier the paper must be calendered. For example, newsprint usually requires just a light calendering with one or two nips. The “nip” is the contact point of two parallel rollers. A multi-nip calendar is required to make high-grade printing and high-gloss paper, like magazine paper.

[0110] There are three types of calendars: machine calendars, soft calendars and multi-nip calendars. Machine calendars usually have 1-2 nips and the rollers are hard. Soft calendars usually have 1-4 nips and at least one of the rollers has a soft polymer coating. Both in machine and soft calendars, one of the two rollers is a heated thermos-roller. A multi-nip calendar usually has 5-11 nips, i.e. 6-12 rollers, with 2-5 of them being thermos-rollers and 4-7 of them polymer coated rollers. A calender can be integrated with a paper or coating machine; as such, it is called an on-line calender. If the calendar is a separate unit, it is called an off-line calender. Paper is fed into an on-line calender from the dryer section of the paper or coating machine. Paper is fed into an off-line calender from a section of the paper or coating machine. Paper is fed into an off-line calender from a reeler. The grade of paper determines the type of calender used. The glossier and smoother the end product, the more rollers, compression and heat required.

[0111] The grade of paper determines the type of calender used. The glossier and smoother the end product, the more rollers, compression and heat required. The calendar section of a paper machine consists of a calender and other equipment. The paper web is run between in order to further smooth it out, which also gives it a more uniform thickness. The pressure applied to the web by the rollers determines the finish of the paper, and there are three types of finish that the paper can have. The first is machine finish, and can range from a rough antique look to a smooth high quality finish. The second is called a super-calendered finish and is a higher degree for fine-screened halftone printing. The third type of finish is called a plater finish, and whereas the first two types of finish are accomplished by the calender stack itself, a plater finish is obtained by placing cut sheets of paper between zinc or copper plates that are stacked together, then put under pressure and heating. A special finish such as a linen finish would be achieved by placing a piece of linen between the plate and the sheet of paper, or else an embossed steel roll might be used.

[0112] There are various calendering methods. The main parameters that separate the methods are the material of the roll surface, the number of nips. The rolls can be steel rollers, polymer surface rollers (typically a steel-polymer pair), or paper rollers.

[0113] Other distinguishing parameters are possible heating and use of moisture. In a hard-nip calender, only the paper deforms while in a soft nip calender, also the polymer surface of the rolls deforms, and the load on the paper is more even leading to lower structural unevenness of paper.

[0114] After calendering, the web has a moisture content of about 6% (depending on the finish). It is wound onto a roll called a tambour, and stored for final cutting and shipping.

[0115] Although the uncalendered paper tends to be uneven in thickness, surprisingly, uncalendered paper expanded slit sheet product produces the optimum properties for use as a packaging wrap. The uniformity of the cells is essentially perfect thereby minimizing or eliminating nesting while maximizing the interlocking of adjacent sheets of expanded paper.

[0116] Preferably, soft calendaring is used and the paper is produced using no more than 3 nips and more preferably, no more than 2 nips. Even more preferably is using no more than 1 nip and most preferably, the paper is uncalendered.

[0117] Preferably, a minimum machine finish is applied to keep the paper from varying too much in thickness across the web. Since the paper width is 20" or less this step is not narrowly critical. The machine finishing is sufficient to decrease the thickness across the paper to a predetermined level. Most preferably, the material used for the slit sheet expandable product is machine finished, uncalendered paper. Finishing is preferably to a degree below the grade required for the first enhanced step for printing.

[0118] Preferably, the paper is the paper used for the fluting in corrugated medium and is processed without any machine finish. Preferably, machine finishing is used for Kraft grades and higher grades. Thus, in contrast to standard practices, substantially uncalendered paper is employed for optimizing the properties of the expanded slit sheet product of the present invention.

[0119] FIG. 1 is the top view of one layer of the slit paper prior to expansion with **100** being the width of the slit and **101** being width of the un-slit dimension. **102** is the distance between the rows.

[0120] FIG. 8 is the top view of one layer of the slit sheet expanded to its three dimensional form with **800** being the open cell area created by the expansion, **801** being the lead wall or land created, and **802** being the connecting leg. It is noted that the terms lead wall and land are used interchangeably to indicate the region **801**.

[0121] FIG. 2 is the side view of slit sheet expanded material, in accordance with the prior art, showing the nesting of two identical layers **201** and **202**, with reference number **203** showing the virtually complete contact between the two layers.

[0122] FIG. 3 is the side view of the use of a separator sheet, in accordance with the prior art, that negates nesting in accordance with the prior art use of a separator sheet **302** between two expanded sheet **301**. The reference number **303** indicates the open space between the separator sheet **302** and an expanded sheet **301**.

[0123] FIG. 4 is a side view of two expanded layers **401** and **402** of the prior art, having regions **403** where side walls of adjacent layer contact each other but nesting is minimized due to the use of differing slit patterns for layers **401** and **402**. Reference numeral **404** illustrates the open space between adjacent layers of expanded sheets which has been substantially maximized due to the differing slit patterns for layers **401** and **402**. It should be understood, that in use, the

dimension difference between the cells of sheets **401** and **402** should be greater than illustrate in order to negate nesting to a greater extent than illustrated in FIG 4.

[0124] FIG. 5 is a side schematic illustration of an expanding operation in accordance with the present invention. The reference numerals **500** and **502** indicate unexpanded slit sheets driven by pinch rubber rollers **503** into the expander rolls section **504** within the internal workings of the automatic expander. Reference numerals **508** and **509** indicate slit sheets **500** and **502** respectively, in their expanded form. The slit paper is feed counterclockwise from a first roll **1402** and clockwise from a second roll **1400** to provide for reversed angles of the lands in accordance with the present invention.

[0125] Expansion rollers **504** employ the hook component **601** of a hook and loop fastener material which covers the front roller section which pulls the slit paper faster than **503** feeds providing the expansion and exiting of the expanded slit paper. For simplicity, the expansion rollers **1606** and **1607** can also be referred to as hook rollers. The driving process is precisely driven with motor **608** that turns drive shaft **607** that has attached two identically drive gear pulleys **604** and **605** that engage the teeth of the drive belt **609**. Timing belt **609** turns gear pulley **603** that is precisely sized to create the 213% ratio to drive pulley **606** attached to timing belt **609**.

[0126] FIG. 7 is a schematic side view of the timing belt **609** and its corresponding teeth **701** that interact with the gear pulleys in FIG. 6 drive gears **603**, **604**, **605**, and **606** that are precisely sized to create the varying speeds that provide the expansion and exit speeds. FIG. 7 shows belt **609** used to rotate the expander rolls **504** and the feed drive rolls **503**. Timing belt **609** turns **504** faster than **503** due to diameter difference for the guides for the two rollers. FIG. 9 is the side perspective view of gear pulley **900** that corresponds in varying sizes to gear pulleys **603**, **604**, **605**, and **606** in FIG. 6. The teeth **901** create the open areas **902** that create the space for the timing belt in **609** FIG. 7 to mesh continuously creating a perfectly timed ratio as the expander system is turned. Gear teeth **701** of FIG. 7 fit within the open spaces between teeth **901** and create the precise drive speeds required.

[0127] In one embodiment one layer can be the soft paper, and the other Kraft. If the slit pattern of the soft and Kraft are the same, the cells would nevertheless tend to be different because of the characteristic differences between soft paper and Kraft. In any event, the use of cells designs that produce mirror image land regions is preferred. The term mirror image, as employed herein, refers to a cell design which produces a desired angle of inclination and by feeding counterclockwise from a first roll **1400** and clockwise from a second roll **1402**, to produce reversed angles of inclinations of the two expanded sheets form the expander. Thus, if the angle of inclination of a first sheet is 60°, then the reverse fed second sheet will have an angle of inclination of 120 degrees, and is identical in form to the first sheet, but with the structure reversed, as by a mirror.

[0128] It has now been found that two adjacent cell orientations are directly affected by the wedge effect from the cutting tool. The sharp edge of the tool is where the knife is at its thinnest. In the case of the hard anvil die cutting system the knife edge penetrates the paper to almost the deepest layer of fibers but never touches the anvil. The un-penetrated paper section of paper is then crushed and

obliterated into paper dust. This enables a complete cut while extending the like of the cutting die dramatically. The knife is made to have a sharp edge and bevels outward from the edge so that it is sturdy. This bevel creates a wedge effect on the paper. Viewing the paper from the side on which the knife first penetrates the paper, the slit entrance side, one can see a wider cut versus the underside which has a much finer looking cut. The wedge effect creates this difference and this difference orients the cells to angle reversely from the direction of manufacturing. If one were to look at the expanded slit sheet at the exit of the cutting die (after cutting is achieved) the cell orientation would inhibit one from look through the expanded slit sheet as it is angled back towards the machine.

[0129] Utilizing the wedge effect so that the cell orientation is backward combined with roll of slit paper where the die cutting comes from underneath the paper, thereby creating an angled forward slit pattern, the cross interlocking effect can be created continuously.

[0130] Preferably, a single slitting device is used to slit a plurality of rolls of expandable paper. Two or more layers of slit sheets are fed to an expander, with the rolls being simultaneously fed alternately clockwise and counterclockwise.

[0131] The use of cell designs that produce mirror image land regions are preferred. The term mirror image, as employed herein, refers to a cell design which produces a desired angle of inclination and by feeding counterclockwise from a first roll **1400** and clockwise from a second roll **1402**, reversed angles of inclinations of the two expanded sheets are produced by the expander. Thus, if the angle of inclination of a first sheet is 60°, then the reverse fed second sheet will have an angle of inclination of 120 degrees, and is identical in form to the first sheet, but with the structure reversed, as in a mirror.

[0132] In another embodiment the slit pattern can be the same for both Kraft layers but the speed of the rolls, and consequently the extent to which the layer expand, would be different, and thus would lessen the amount of nesting. It should be noted that the tendency of the two layers to “relax” can cause the cell structures to be the same even though the expansion was different. Thus, the use of different slit patterns is preferred in order to optimize the ability to negate nesting.

[0133] It is important to note that the maximum stretch provides the best cushioning. The product works while under tension. It is easier to maintain that tension with the system of the present invention than with the system of U.S. Pat. Nos. 5,538,778 and 5,782,753 because the interlocking of layers serves to maintain the slit sheet under tension.

[0134] Pre-expanded material formed in accordance with the system of U.S. Pat. Nos. 5,338,778 and 5,782,753 is not as stretched as much as it should be. There is a limitation to the stretching, due to the tissue and slit papers being on the same roll and therefore cannot be independently tensioned. Therefore the tissue gets taut and the slit sheet paper does not. The new art eliminates the use of the tissue paper separator sheet, in both the expander process or the pre-expanded process, a better expansion can be obtained due to the absence of interference from the tissue separator sheet.

[0135] The cell opening effect orients the lead wall to be either angled forward in the machine direction or angled backward from the machine direction. Angled forward orients the cells such that if one were to look downward at the

cells in front of the expanding web, as the operator would, one would be able to see through the slit sheet material. If the angle is backward then the operator would see the rows of lead walls such that it is not possible to see through the expanded sheet material.

[0136] Attention is invited to FIG. 9 of U.S. Pat. No. 5,699,578 which illustrates the angled orientation of the cells of the expanded slit paper and the nesting that occurs when one sheet is laid over another layer of expanded slit paper having substantially the same angled orientation.

[0137] It has now been found that orienting the rolls of unexpanded slit sheet material onto the rollers of the expander such that the exit surface of a first slit paper sheet faces the exit surface of the other sheet, or the slit entrance surface of a first slit paper sheet face the slit entrance surface of the other sheet, upon expansion, creates a crisscross pattern of expanded sheets. This crisscross pattern creates a more resilient and firmer material than two sheets oriented in the same direction. The crisscross expanded sheets can nest to some degree, up to approximately 50% but due to the increase in resiliency the product becomes actually stronger and not able to nest further. Lighter weight paper can be used to maintain the same resiliency as non-crisscross product as well as reducing costs in paper and tooling. The degree of nesting is directly related to the angle of inclination of the lands schematically represented in FIGS. 10-12. Looking now at FIG. 10 the lead walls/lands **1001** are oriented backward to the manufacturing direction **1006** which is also the direction the expanded sheets exit the expander. This causes the eye of an operator **1005** facing the web to be inhibited from seeing through the expanded sheet but see the surface areas of the lead walls **1001**.

[0138] Looking now at FIG. 11 the lead walls **1003** are oriented forward in the manufacturing direction **1006** which is also the direction the expanded sheets exit the expander. This causes the eye of an operator **1005** facing the web to be able to see through the expanded sheet layer.

[0139] FIG. 12 combines the forward and backward layers of FIG. 10 and FIG. 11 to create a crisscross pattern with the lead walls in the backward direction interacting and bisecting lead walls **1003** leaving open spaces **1002** and **1004**.

[0140] As shown in FIG. 12, a first layer having lead walls **1001** are oriented backward to the manufacturing direction **1006**, that is, the direction in which the paper travels during the slitting operation. With respect to the plane of the slit paper the lead walls **1001** are oriented backward thus forming an angle of less than 90° to the plane of the paper while the forward oriented lead walls form an angle of greater than 90° to the plane of the paper.

[0141] The arc represented by reference number **1200** thus must be much greater than 0° and much less than 180°, and can range from 135 to 15 degrees, and preferable from 90 to 30 degrees, and most preferably is in the range from 60 to 30 degrees. It should be understood that the arc can vary across regions of the paper and need not be narrowly uniform. It should also be understood that the closer the angle of the lead walls to the vertical, the thicker the composite structure.

[0142] The arc represented by reference numeral **1010** can range from 50° to 85° and the angle of inclination **1012** of the second layer is in the range from 130° to 95°. The angles of the lands **1001** and **1003** are relative to the plane **1008** of the unexpanded sheet material. Preferably, the angle of inclination of the first layer is in the range from 55° to 75°

and optimally in the range from 55° to 65°. Preferably, the angle of inclination of the second layer is in the range from 125° to 105° and optimally in the range from 125° to 115°. The angles of inclination of the two adjacent expanded sheets can be different, provided that they are in ranges previously noted, and provided the slit patterns, though different, produce at least about the same, or the same number of lands per inch such that the adjacent lands interlock as shown in FIG. 12. Thus, angles of inclination **1010** and **1012** can be different, provided the cell dimensions produce consistent interlocking as illustrated in FIG. 12. The space **102**, as illustrated in FIG. 1, can be varied to produce varying angles of inclination.

[0143] In another embodiment of the invention, adjacent layers have substantially the same slit patterns that produce sheets which when expanded, the first layer has lands that are at an angle in the range from 50° to 85° and the angle of inclination of the second layer is in the range from 130° to 95°. Preferably, the angle of inclination of the first layer is in the range from 55° to 75° and optimally in the range from 55° to 65°. Preferably, the angle of inclination of the second layer is in the range from 125° to 105° and optimally in the range from 125° to 115°. It should be noted that the angle of inclination of the second layer is a mirror image of the angle of inclination of the first layer, thus, if the first layer has an angle of inclination of 60°, the second layer has an angle of inclination of 120°. In this embodiment, the sum of the angles of inclination of the first and second sheet is 180°.

[0144] FIG. 13 shows that the reverse orientation of the adjacent layers of expanded sheet material serves to reduce nesting. It has been found that the low level of nesting which is exhibited by the mirror image adjacent layers serves to reinforce the composite structure due to an interlocking effect. Nevertheless the result is a thicker composite structure than is obtained from a composite structure in which is not cross-expanded. The term "cross-expanded" as applied to a composite expanded slit sheet material means a structure in which there is a combination of a backward orientation of the lead walls of a first expanded slit sheet or web and a forward orientation of the lead walls of an adjacent web, as shown in FIG. 13.

[0145] The cell dimensions are selected to provide the minimum amount or overlap of layers, that is, minimum nesting, in order to get the maximum product height. However, there must be overlap of layers to get sufficient interlocking. The amount of overlap depends on the angle of the lands that are interlocking. The interlocking of the reversed angle layers serves to inhibit retraction of expanded sheets and provides optimum product resiliency.

[0146] Looking at the system from another angle, you want 100% retained expansion but that is not feasible. The interlocking system of the present invention can provide at least 75% retention of expanded length as compared to less than 75% retention of expanded length using the system of U.S. Pat. No. 5,688,578. The controlled/limited interlocking of layers changes the properties of the wrap compared to the interleaf design because it resists flattening of the layer when under a load. In the interleaf design, the two peripheral nest regions merely nest without resisting flattening of the layers under load. The present invention produces a product having greater resiliency and load bearing capacity as compared to an interleaf design.

[0147] As illustrated in FIG. 14, the feed roller **1400** is seen to rotate counter to feed roller **1402** thus orienting the

rolls of unexpanded slit sheet material onto the rollers of the expander such that the exit surface of a first slit paper sheet faces the exit surface of the other sheet, or the slit entrance surface of a first slit paper sheet face the slit entrance surface of the other sheet, upon expansion, creates a crisscross pattern of expanded sheets. The expansion process with the Expander of FIG. 14 is illustrated in FIG. 5.

[0148] FIG. 15 is the offset layer where 1501 is hexagonal cell wall A that is one to six degrees (1-6) offset from parallel and 1502 is hexagonal cell that is offset minus one to minus six degrees (-1 to -6) from parallel with a combined offset between the adjacent cells of two to twelve degrees (2-12).

[0149] FIG. 16 is the side view of the alternate vertically expanded expander where 1600 is the packing table. 1601 and 1602 are the flat slit sheet material where 1601 unwinds counter clockwise and 1602 unwinds clockwise to make the opposing roll non-nesting interlocking design. Rubber rollers 1603 pinch the material and pull the slit sheet material from rollers 1601 and 1602. The rubber rollers 1603 can either be powered or not powered. If it is not powered then powered Expansion rollers 1606 and 1607 pull the expanded slit sheet material 1608 from the friction feed rubber rollers 1603 and the precise friction applied provides the ratio of speeds necessary to provide expansion. Alternatively, rubber rollers 1603 can be powered at a lower rotational speed than the hook rollers 1606 and 1607. The expansion area 1604 is comprised of a vacuum box 1612 that removes paper dust created from sitting of the slit sheet material. The vacuum 1610 pulls creates air suction and pulls air from hose 1611 and thus air from 1612 providing return air from vacuum box 1612. After expansion roller 1605 guides the expanded material 1608 into the Expansion roller chamber and Expansion rollers 1606 and 1607 drive the material onto the packing table 1600.

[0150] FIG. 17 is a schematic side view of an alternate expanded expander in which a pair of feed rollers 1700 and 1701 feed slit paper 1703 and 1702 respectively, to two pairs of pinch rollers 1706 and 1707, and 1704 and 1705. The slit paper 1708 expands in the region between the pinch rollers 1704 and 1705 and the pair of expansion rollers 1710 and 1711. Similarly, the slit paper 1709 expands in the region between the pinch rollers 1706 and 1707 and the pair of expansion rollers 1710 and 1711. the expanded sheets 1708 and 1709 are brought together between the expansion rollers 1710 and 1711 to form interlocked composite layer 1712. The use of two sets of pinch rollers enables a separation between adjacent slit sheets to be provided between the sheets at the initial region of expansion. Once the cells are expanded the material does not reverse so it is only the very beginning of the expansion where this is vital for the cells to act based on the wedge effect of the tool as disclosed in co-pending applications 62,025,536, filed Jul. 17, 2014 and Ser. No. 14/480,319, filed Sep. 8, 2014.

[0151] FIG. 18 shows an expander having two feed rollers 1800 and 1801, two guide rollers 1814 and 1816, and two sets of pinch rollers 1804-1805 and 1806-1807.

[0152] The 1st expanded sheet material 1802 is shown forming an expansion initiation region 1809 and the 2nd expanded sheet material 1803 is shown forming an expansion initiation region 1808. Expansion initiation regions are between the pinch roller pairs 1804-1805 and 1806-1807 and the expansion roller pair 1811 and 1810. The final product is the expanded interlocked sheets 1812.

[0153] FIG. 19 shows an alternate expander embodiment having two feed rollers 1800 and 1801. Slit sheets 1802 and 1803 are fed to a pair of pinch rollers 1906 and 1907. The two sheets are maintained in a spaced relationship through the use of a pair of guide rollers 1914 and 1916. The sheets are feed to the expansion roller pair 1811 and 1810. Expansion initiation regions are between guide rollers 1914 and 1916 and expansion roller pair 1811 and 1810. The final product is the expanded interlocked sheets 1812.

[0154] FIG. 20 shows an alternate expander embodiment in which the expansion initiation regions are maintained spaced apart through the use of two pairs of pinch rollers 1804-1805 and 1806-1807 and two pairs of expansion rollers 2010-2011 and 2010A-2011A. An expansion initiation region 2020 is illustrated between the two pairs of pinch rollers 1804-1805 and 1806-1807 and the two pairs of expansion rollers 2010-2011 and 2010A-2011A.

[0155] Interlocking of Adjacent Layers of Expanded Slit Sheets

[0156] Both the slit sheets of U.S. Pat. No. 5,782,735 and those of the present invention, cannot line up perfectly to get maximum height. No flexible slit sheet product could align legs on each other that are at 90° with respect to the plane of the unexpanded slit sheet material. Thus, the maximum thickness of a layer of expanded sheet material is less than the height of land areas that are at 90°.

[0157] The lands 2020 and 2032 of FIG. 20 of U.S. Pat. No. 5,782,735 want to nest because there is a perfectly sized cell of the upper sheet wanting to perfectly fit into the lower cell especially when under tension. The tension shapes the hexagon and angles it perfectly with respect to the angles of the adjacent layer as illustrated in FIG. 2 of '735.

[0158] The product of the present invention employs opposing angles for layers of expanded sheets and thereby uses the tension to maximize height. As an operator stretches the lower leg of the upper expanded sheet finds its rest towards the top of the lower sheet. With a loss of tension the leg will skip downward but can never fully nest.

[0159] By way of contrast with the present invention, the slit sheets of '735 nest completely, or near completely, as diagrammatically illustrated in FIG. 9 of the '735 patent, and thus there is a need for interleaf of U.S. Pat. No. 5,688,578, as illustrated in FIG. 8 of '578.

[0160] Manufacture of Slit Sheets

[0161] It is essential that the cells open upon expansion to form lands that consistently align in the same direction as illustrated in FIGS. 10 and 11. It has been found that during the expansion process, the angle of inclination of the lands periodically reverse such that at some unpredictable position along the length of the expanded paper, the angle of inclination of the lands "switch back", from a forward to a rearward inclination and vice versa. The switch back effect causes some regions of a sheet of expanded paper to be inclined as illustrated in FIG. 10, and then reverse to an inclination as illustrated in FIG. 11. The switch back does not occur simultaneously for both sheets of expanded paper and thus there can be regions in which the angle of inclination is the same for both sheets and the calls of the sheets nest in each other.

[0162] It has now been found that layers of expanded slit sheets in which adjacent sheets consistently have lands with angles of inclination that are substantially reversed from each other, interlock over substantially the entire length of the sheets and preferably, over the entire length of the sheets,

thereby producing an improved packing material as compared to prior art products. Preferably the angles of inclination one of the adjacent sheets is the mirror image of the angles of inclination of the lands of the other of the adjacent sheets.

[0163] It has now been found that the method and devices for slitting of the paper has a direct relationship to the tendency of the angle of inclination of the lands to reverse during the expansion step. While it is necessary to produce slit sheets that expand uniformly and consistently over substantially the entire length of the sheets and preferably, over the entire length of the sheets. It is not narrowly critical as to what technique is used to produce slit sheet that uniformly expand to produce a consistent angle of inclination of the lands, that is, free of regions that switch back.

[0164] The blade used to slit the paper is beveled to produce a sharp edge and the sharpness must be maintained to prevent the switching effect from causing a reversal of the angle of inclination of the land region of the cells.

[0165] The slitting operation can employ blades that press through the paper to a hard anvil or blades that cut through the paper to a soft round anvil. The tool and anvil rotate at the same speed as the paper sheet thus cutting with high precision making the slit sheet material. The sharp edge is made with a beveled edge which means that it becomes increasingly narrower until it is a fine sharp edge from the cylinder to the sharp edge. This creates a wedge effect on the paper that it is cutting. Even though the paper is only 0.004-0.012" the wedge effect is enough to produce a cell opening effect. The surface of the sheet material that the blade edge initially contacts, that is, the blade entrance surface is called the slit entrance or obverse side of the paper. The surface that the blade exits is called the exit or reverse surface of the sheet material.

[0166] To produce expansion of the slit paper and form lands with an angle of inclination that is consistent along the entire length of the expanded sheet, one side of the cutting edge of the blade is at an angle of substantially less than 90° with respect to the plane of the paper and the other side of the cutting edge of the blade is at an angle of at least 90° with respect to the plane of the paper, and preferably at an angle of 90°.

[0167] The wedging action of the slit forming blade forces one edge of a slit to be below the plane of the slit sheet, at least at the opposing ends of the slit, thus biasing the cells toward a consistent opening angle during the expansion step.

[0168] Virgin paper can be thinner than recycled paper and can provide equivalent strength based on the longer cellulose fibers. However, the thinner paper will be less affected than a recycled thicker paper equivalent and thus would need a shallower bevel angled knife to achieve the requisite slitting properties.

[0169] While the invention has been described in terms of several preferred embodiments, it should be understood that there are many alterations, permutations, and equivalents that fall within the scope of this invention. It should also be noted that there are alternative ways of implementing both the process and apparatus of the present invention. For example, steps do not necessarily need to occur in the orders shown in the accompanying figures, and may be rearranged as appropriate. It is therefore intended that the appended claim includes all such alterations, permutations, and equivalents as fall within the true spirit and scope of the present invention.

[0170] All reference, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

[0171] The use of the terms "a" and "an" and "the" and similar references in the context of this disclosure (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., such as, preferred, preferably) provided herein, is intended merely to further illustrate the content of the disclosure and does not pose a limitation on the scope of the claims. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the present disclosure.

[0172] Multiple embodiments are described herein, including the best mode known to the inventors for practicing the claimed invention. Of these, variations of the disclosed embodiments will become apparent to those of ordinary skill in the art upon reading the foregoing disclosure. The inventors expect skilled artisans to employ such variations as appropriate (e.g., altering or combining features or embodiments), and the inventors intend for the invention to be practiced otherwise than as specifically described herein.

[0173] Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

[0174] The use of individual numerical values is stated as approximations as though the values were preceded by the word "about", "substantially", or "approximately." Similarly, the numerical values in the various ranges specified in this application, unless expressly indicated otherwise, are stated as approximations as though the minimum and maximum values within the stated ranges were both preceded by the word "about", "substantially", or "approximately." In this manner, variations above and below the stated ranges can be used to achieve substantially the same results as values within the ranges. As used herein, the terms "about", "substantially", and "approximately" when referring to a numerical value shall have their plain and ordinary meanings to a person of ordinary skill in the art to which the disclosed subject matter is most closely related or the art relevant to the range or element at issue. The amount of broadening from the strict numerical boundary depends upon many factors. For example, some of the factors which may be considered include the criticality of the element and/or the effect a given amount of variation will have on the performance of the claimed subject matter, as well as other consideration known to those of skill in the art. As used herein, the use of differing amounts of significant digits for different numerical values is not meant to limit how the use of the words "about", "substantially", or "approximately" will serve to broaden a particular numerical value or range. Thus, as a general matter, "about", "substantially", or

“approximately” broaden the numerical value. Also, the disclosure of ranges is intended as a continuous range including every value between the minimum and maximum values plus the broadening of the range afforded by the use of the term “about”, “substantially”, or “approximately”. Thus, recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. To the extent that determining a given amount of variation of some of the factors such as the criticality of the slit patterns, paper width differential pre- and post-expansion, paper weights and type, as well as other considerations known to those of skill in the art to which the disclosed subject matter is most closely related or the art relevant to the range or element at issue will have on the performance of the claimed subject matter, is not considered to be within the ability of one of ordinary skill in the art, or is not explicitly stated in the claims, then the term “about”, should be understood to mean the numerical value, plus or minus 15% and the terms “substantially”, and “approximately” should be understood to mean the numerical value, plus or minus 5%.

[0175] It is to be understood that any ranges, ratios and ranges of ratios that can be formed by, or derived from, any of the data disclosed herein represent further embodiments of the present disclosure and are included as part of the disclosure as though they were explicitly set forth. This includes ranges that can be formed that do or do not include a finite upper and/or lower boundary. Accordingly, a person of ordinary skill in the art most closely related to a particular range, ratio or range of ratios will appreciate that such values are unambiguously derivable from the data presented herein.

What is claimed is:

1. The method of expanding slit sheet material that upon expansion, form two or more layers of interlocking hexagonal cells,

comprising the steps of expanding a slit sheet, wrapping the expanded slit sheet around a product and forming at least two layers of overlying layers, said overlying layers forming layers being in direct contact with substantially across the width of the layers, with adjacent layers having differing angles of inclination of the land areas, and adjacent layers having interlocking patterns

wherein expanded layers resist contraction and nesting.

2. The method of expanding slit sheet material that upon expansion, form two or more layers of interlocking hexagonal cells,

comprising the steps of expanding a first slit sheet material,

expanding a second slit sheet material, said first slit sheet material being in interlocking contact with said second slit sheet material,

wrapping the expanded first slit sheet material and said second slit sheet material around a product and forming at least two layers of overlying layers,

said overlying layers forming layers in direct contact substantially across the width of the layers, with adjacent layers having differing angles of inclination of the land areas, and adjacent layers having interlocking patterns,

wherein expanded layers resist contraction and nesting.

3. The method of claim 2, wherein said first slit sheet material is fed to an expansion region from a first roll of slit sheet material and said second slit sheet material is fed to said expansion region from a second roll of slit sheet material.

4. The method of claim 2, wherein said first and said second slit sheet material neck down due to the steps of expanding said first slit sheet material and expanding said second slit sheet material.

5. A method of protecting a object for shipping by wrapping and cushioning said object in an expanded sheet material, said expanded sheet material in expanded form being at least one sheet of extendible sheet material said at least one sheet of extendible sheet material being flexible, non-woven fibrous material, having a plurality of spaced parallel rows of individual slits in a slit pattern extending transversely from one end of the fibrous sheet material to the opposing end of said at least one sheet, each of said rows having interval spaces between consecutive slits, said slits in each row being positioned adjacent the interval space between consecutive slits in the adjacent parallel row of slits, comprising the steps of:

a) expanding a length of at least one sheet of an extendible sheet material by extending the opposing ends of said at least one sheet, to form at least one expanded sheet having an array of openings,

said flexible, non-woven fibrous sheet material and said slit pattern, in combination producing an extendible sheet characterized by

i) forming upon expansion, an array of hexagonal openings, said openings being bound by land areas and leg areas, and being generally similar in shape and size, DELETED in a consistent, uniformly repeating pattern, and opening in generally a continuous non-repeatable pattern extending transversely from one end of the fibrous sheet to the opposing end and also adjacent to the first set of rows non-repeatable traversing from one end to the opposing end of the fibrous sheet material.

ii) said land areas being dually rotatable to an angle of at least about 45 degrees and less than 90 degrees and rotatable to an angle of at least 135 degrees and less than 90 degrees from its unexpanded position in the direction of,

b) wrapping said at least one expanded sheet around an object, and

c) placing the wrapped object in a package.

6. A method of protecting an object for shipping by wrapping and cushioning said object in a combination of two sheet layer expanded sheet material, said expanded sheet material in expanded form being at least one sheet of extendible sheet material said at least one sheet of extendible sheet material being rotatable to an angle of at least about 45 degrees and less than 90 degrees from its unexpanded position being flexible, non-woven fibrous material, having a plurality of spaced parallel rows of individual slits in a slit pattern extending transversely from one end of the fibrous sheet material to the opposing end of said at least one sheet, each of said rows having interval spaces between consecutive slits, said slits in each row being positioned adjacent the interval space between consecutive slits in the adjacent parallel row of slits, combined with one sheet of extendible sheet material said at least one sheet of extendible sheet material being rotatable to an angle of at least about 135 degrees and less than 90 degrees from its unexpanded

position being flexible, non-woven fibrous material, having a plurality of spaced parallel rows of individual slits in a slit pattern extending transversely from one end of the fibrous sheet material to the opposing end of said at least one sheet, each of said rows having interval spaces between consecutive slits, said slits in each row being positioned adjacent the interval space between consecutive slits in the adjacent parallel row of slits comprising the steps of:

- a) expanding a length of at least two sheets of an extendible sheet material by extending the opposing ends of said at least one sheet, to form at least a two layer expanded sheet having an array of openings, said flexible, non-woven fibrous sheet material and said slit pattern, in combination producing an extendible sheet characterized by
 - i) forming upon expansion, an array of hexagonal openings, said openings being bound by land areas and leg areas,

and being generally similar in shape and size, with each layer comprising of a consistent, uniformly repeating pattern with;

- ii) the first layer having said land areas being rotatable to an angle of at least about 45 degrees and less than 90 degrees and;
- iii) said second layer having said land areas being rotatable to an angle of at least about 135 degrees and greater than 90 degrees.
- ii) said land areas being rotatable to an angle of at least about 45 degrees and less than 90 degrees from its unexpanded position,
- b) wrapping said two expanded sheets around an object, and
- c) placing the wrapped object in a package.

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