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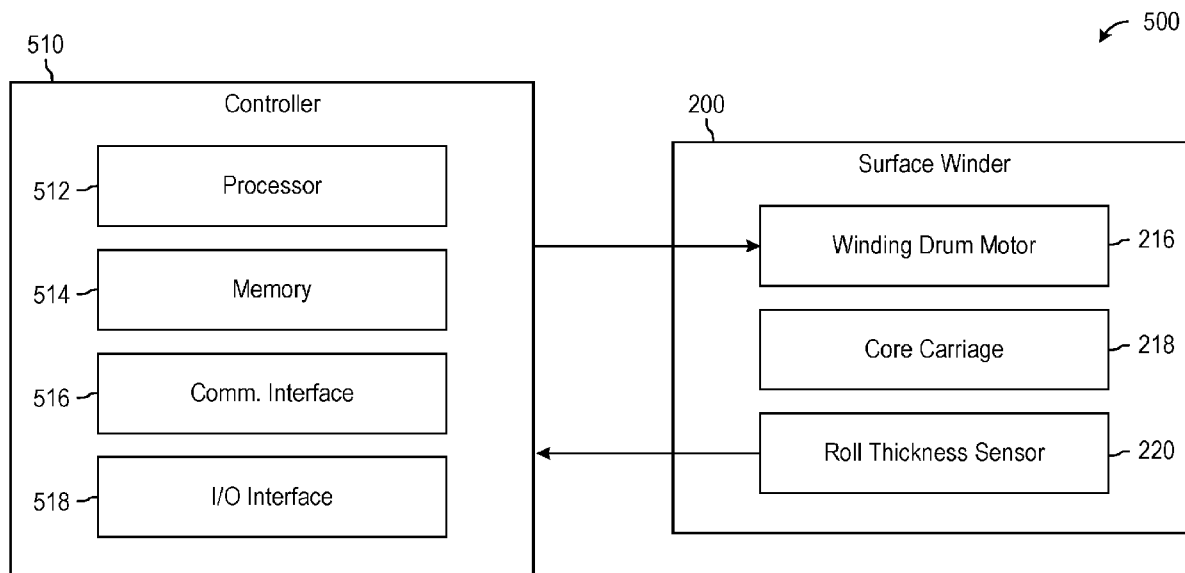


FIG. 5

(57) **Abstract:** A method of manufacturing nonwoven material includes feeding a nonwoven web across a winding drum and onto a core; operating the winding drum to wind the nonwoven web around the core to form a roll of the nonwoven web; and controlling a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first magnitude, and ii) subsequently decreased by a second magnitude, wherein the second magnitude is less than the first magnitude, and wherein the periodic increasing and subsequent decreasing of the draw is repeated until the roll reaches a threshold diameter.

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VARIABLE SURFACE WINDER DRAW FOR WINDING NONWOVEN WEB

BACKGROUND

[0001] Nonwoven web refers to a sheet-like structure composed of randomly or semi-randomly arranged fibers or filaments that are mechanically, chemically, or thermally bonded together. Unlike traditional textiles that are woven or knitted, nonwoven webs are manufactured by directly forming a web of fibers or filaments and then bonding them together without the need for interlacing or knitting. Coform nonwoven webs or “coform materials” are a form of nonwoven web that is a composite of two or more materials, often including a mixture or stabilized matrix of thermoplastic fibers and a second material. Examples of the second material include absorbent fibrous organic materials (e.g., woody pulp), non-wood pulp (e.g., cotton, rayon, recycled paper, and pulp fluff), superabsorbent materials (e.g., superabsorbent particles and fibers), inorganic absorbent materials, treated polymeric staple fibers, and other materials (e.g., non-absorbent staple fibers, non-absorbent particles, and the like). In some cases, coform nonwoven webs can contain an absorbent material (e.g., pulp fibers) and can be used in a wide variety of applications, including wet wipes.

[0002] During production, coform material is typically wound onto large rolls for storage and transport. For example, rolls of coform material may be transported to a manufacturing line to be unwound and packaged to produce various products, such as wet wipes (e.g., flushable wet wipes). Variability in the coform material thickness (e.g., the thickness of the coform nonwoven web) due to winding onto a roll during production can cause significant issues when producing products downstream (e.g., “converting”). For example, through-roll coform thickness variability can lead to an undesirable lack of uniformity among end-user products, such as wet wipes. Furthermore, through-roll coform thickness variability in moist wipe production can cause stacker crashes, pouch wrapper jams, lid misplacement, and numerous other problems across various coform converting assets. These and other issues caused by coform thickness variability generate waste, cause delays, and can potentially introduce safety hazards due to increased human-machine interactions (e.g., increased roll change frequency, correction or removal of jams, etc.).

SUMMARY

[0003] One implementation of the present disclosure is a method of manufacturing nonwoven material, the method including: feeding a nonwoven web across a winding drum and onto a core; operating the winding drum to wind the nonwoven web around the core to form a roll of the nonwoven web; and controlling a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first magnitude, and ii) subsequently decreased by a second magnitude, wherein the second magnitude is less than the first magnitude, and wherein the periodic increasing and subsequent decreasing of the draw is repeated until the roll reaches a threshold diameter.

[0004] Another implementation of the present disclosure is a controller for a machine including a winding drum that winds a nonwoven web onto a core to form a roll, the controller including: one or more processors; and memory having instructions stored thereon that, when executed by the one or more processors, cause the controller to: operate the winding drum to wind the nonwoven web around the core to form the roll; and control a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first magnitude, and ii) subsequently decreased by a second magnitude, wherein the second magnitude is less than the first magnitude, wherein the periodic increasing and subsequent decreasing of the draw is repeated until the roll reaches a threshold diameter.

[0005] Yet another implementation of the present disclosure is a system for producing a roll of nonwoven web, the system including: a winding drum for winding the nonwoven web onto a core to form the roll; and a controller that operates the winding drum to: control a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first amount, and ii) subsequently decreased by a second amount, wherein the second amount is less than the first amount such that the draw of the winding drum is higher after decreasing by the second amount than it was prior to increasing by the first amount for each periodic increase and decrease of the draw.

[0006] Additional features will be set forth in part in the description which follows or may be learned by practice. The features will be realized and attained by means of the elements and

combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a diagram of an example method for forming a coform nonwoven web, according to some implementations.

[0008] FIG. 2 is a diagram of a surface winder configured to wind nonwoven web, according to some implementations.

[0009] FIG. 3 is a graph of height variability in stacked nonwoven web sheets, according to some implementations.

[0010] FIG. 4A is a graph comparing stack height variability in stacks of sheets produced from rolls of nonwoven web that were wound using a constant draw, according to some implementations.

[0011] FIG. 4B is a graph comparing stack height variability in stacks of sheets produced from rolls of nonwoven web that were wound using a variable draw, according to some implementations.

[0012] FIG. 5 is a block diagram of a system for producing rolls of nonwoven web, according to some implementations.

[0013] FIG. 6 is a graph of a step waveform draw profile for surface winders, according to some implementations.

[0014] FIG. 7 is a detailed view of the step waveform draw profile of FIG. 6, according to some implementations.

[0015] FIG. 8 is a flow diagram of a process for producing a roll of nonwoven web, according to some implementations.

[0016] FIG. 9 is a flow diagram of a process for variably controlling a surface winder based on a step waveform draw profile, according to some implementations.

[0017] FIG. 10A is a schematic view of an apparatus and process for converting nonwoven materials into stacks of sheets, according to some implementations.

[0018] FIG. 10B is an enlarged side view of a portion of the apparatus shown in FIG. 10A, according to some implementations.

[0019] FIG. 10C is an enlarged front view of a portion of the apparatus shown in FIG. 10A, according to some implementations.

[0020] FIG. 11A is a perspective view of an example dispensing container for a stack of sheets produced from a nonwoven material, according to some implementations.

[0021] FIG. 11B is a perspective view of the example dispensing container shown in FIG. 11A where the container is opened, according to some implementations.

[0022] FIG. 12 is another graph comparing stack height variability in stacks of sheets produced from rolls of nonwoven web that were wound using a constant draw and a variable draw, according to some implementations.

[0023] FIG. 13 is a graph comparing the rate of change of average clip height in stacks of sheets produced from rolls of nonwoven web that were wound using a constant draw and a variable draw, according to some implementations.

[0024] Various objects, aspects, and features of the disclosure will become more apparent and better understood by referring to the detailed description taken in conjunction with the accompanying drawings, in which like reference characters identify corresponding elements throughout. In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements.

DETAILED DESCRIPTION

[0025] Referring generally to the figures, a method and corresponding systems and devices for winding nonwoven web onto rolls are shown, according to various implementations. In particular, a variable draw winding method and related systems and devices are described which address variability in nonwoven web thickness, e.g., due to winding via a surface winder. While generally described herein with respect to coform nonwoven webs, it should be appreciated that the disclosed method and corresponding systems and devices can be used to wind any type of

nonwoven material into a roll. As such, the following disclosure is not intended to be limited to only coform nonwoven webs.

[0026] The disclosed method generally includes periodically increasing and subsequently decreasing the draw of a surface winder (e.g., by varying the speed of a winding drum(s)) to respectively increase and decrease a tension on a coform nonwoven web being wound about a core. In some implementations, for each periodic increase and decrease, the draw is increased by a greater magnitude than it is decreased. When plotted, the disclosed method generally results in a positive sloped “sine wave-like” or “stair-stepped” winding profile that provides a compression relief layer every few inches of roll diameter. This creates a cushion effect, providing a more constant through-roll thickness of the coform nonwoven web by preventing each layer of the roll from compressing all the layers under it as the diameter of the roll expands. In some implementations, the method is implemented via a controller that controls a speed of the winding drum(s) of a surface winder.

Nonwoven Web

[0027] As used herein the term “nonwoven web” generally refers to a web having a structure of individual fibers or threads which are interlaid, but not in an identifiable manner as in a knitted fabric. Examples of suitable nonwoven fabrics or webs include, but are not limited to, meltblown webs, spunbond webs, bonded carded webs, airlaid webs, coform webs, hydraulically entangled webs, and so forth.

[0028] As used herein, the term “meltblown web” generally refers to a nonwoven web that is formed by a process in which a molten thermoplastic material is extruded through a plurality of fine, usually circular, die capillaries as molten fibers into converging high velocity gas (e.g., air) streams that attenuate the fibers of molten thermoplastic material to reduce their diameter, which may be to microfiber diameter. Thereafter, the meltblown fibers are carried by the high velocity gas stream and are deposited on a collecting surface to form a web of randomly dispersed meltblown fibers. Such a process is disclosed, for example, in U.S. Pat. No. 3,849, 241 to Butin, et al. Generally speaking, meltblown fibers may be microfibers that are substantially continuous or discontinuous, generally smaller than 10 micrometers in diameter, and generally tacky when deposited onto a collecting surface.

[0029] As used herein, the term “spunbond web” generally refers to a web containing small diameter substantially continuous fibers. The fibers are formed by extruding a molten thermoplastic material from a plurality of fine, usually circular, capillaries of a spinneret with the diameter of the extruded fibers then being rapidly reduced as by, for example, educative drawing and/or other well-known spunbonding mechanisms. The production of spunbond webs is described and illustrated, for example, in U.S. Pat. No. 4,340,563 to Appel, et al., U.S. Pat. No. 3,692,618 to Dorschner, et al., U.S. Pat. No. 3,802,817 to Matsuki, et al., U.S. Pat. No. 3,338,992 to Kinney, U.S. Pat. No. 3,341,394 to Kinney, U.S. Pat. No. 3,502,763 to Hartman, U.S. Pat. No. 3,502,538 to Levy, U.S. Pat. No. 3,542,615 to Dobo, et al., and U.S. Pat. No. 5,382,400 to Pike, et al. Spunbond fibers are generally not tacky when they are deposited onto a collecting surface. Spunbond fibers may sometimes have diameters less than about 40 micrometers and are often between about 5 to about 20 micrometers.

[0030] The synthetic fibers employed in the coform nonwoven web may be formed from a variety of different thermoplastic polymers as is known in the art, such as polyolefins (e.g., ethylene polymers, propylene polymers, polybutylene, etc.); polytetrafluoroethylene; polyesters (e.g., polyethylene terephthalate, polylactic acid, etc.); polyvinyl acetate; polyvinyl chloride acetate; polyvinyl butyral; acrylic resins (e.g., polyacrylate, polymethylacrylate, etc.); polyamides, (e.g., nylon); polyvinyl chloride; polyvinylidene chloride; polystyrene; polyvinyl alcohol; polyurethanes; and so forth, as well as mixtures of various polymers. Because many synthetic thermoplastic fibers are inherently hydrophobic (i.e., non-wettable), such fibers may optionally be rendered more hydrophilic (i.e., wettable) by treatment with a surfactant solution before, during, and/or after web formation. Other known methods for increasing wettability may also be employed, such as described in U.S. Pat. No. 5,057,361 to Sayovitz, et al.

[0031] The synthetic fibers may be monocomponent or multicomponent. Monocomponent fibers are generally formed from a polymer or blend of polymers extruded from a single extruder. Multicomponent fibers are generally formed from two or more polymers (e.g., bicomponent fibers) extruded from separate extruders. The polymers may be arranged in substantially constantly positioned distinct zones across the cross-section of the fibers. The components may be arranged in any desired configuration, such as sheath-core, side-by-side, pie, island-in-the-sea, three island, bull’s eye, or various other arrangements known in the art.

Various methods for forming multicomponent fibers are described in U.S. Pat. No. 4,789,592 to Taniguchi et al. and U.S. Pat. No. 5,336, 552 to Strack et al., U.S. Pat. No. 5,108,820 to Kaneko, et al, U.S. Pat. No. 4,795,668 to Kruege, et al, U.S. Pat. No. 5,382,400 to Pike, et al, U.S. Pat. No. 5,336,552 to Strack, et al, and U.S. Pat. No. 6,200,669 to Mamon, et al. Multicomponent fibers having various irregular shapes may also be formed, such as described in U.S. Pat. No. 5,277,976 to Hogle, et al, U.S. Pat. No. 5,162,074 to Hills, U.S. Pat. No. 5,466,410 to Hills, U.S. Pat. No. 5,069,970 to Largman, et al, and U.S. Pat. No. 5,057,368 to Largman, et al.

[0032] In some implementations, synthetic fibers are formed using a variety of known processes. For example, the fibers may include spunbond fibers, meltblown fibers, as well as a combination thereof. With respect to meltblown fibers, a melt flow rate of the thermoplastic composition used to form the fibers may be selected within a certain range to optimize the properties of the resulting fibers. The melt flow rate is the weight of a polymer (in grams) that may be forced through an extrusion rheometer orifice (0.0825-inch diameter) when subjected to a force of 2160 grams in 10 minutes at 230° C. Generally speaking, the melt flow rate is high enough to improve melt processability, but not so high as to adversely interfere with the ability of the web to be laminated to the cellular film in the desired manner. Thus, in most implementations of the present disclosure, the thermoplastic composition used to form the synthetic fibers has a melt flow rate of from about 200 to about 6000 grams per 10 minutes, in some implementations from about 300 to about 3000 grams per 10 minutes, and in some implementations, from about 400 to about 1500 grams per 10 minutes, measured in accordance with ASTM Test Method D1238-E at a load of 2160 grams at 230° C.

[0033] Any absorbent material may generally be employed in the coforn nonwoven web, such as absorbent fibers, particles, etc. In one implementation, the absorbent material includes fibers formed by a variety of pulping processes, such as kraft pulp, sulfite pulp, thermomechanical pulp, etc. The pulp fibers may include softwood fibers having an average fiber length of greater than 1 mm and particularly from about 2 to 5 mm based on a length-weighted average. Such softwood fibers can include, but are not limited to, northern softwood, southern softwood, redwood, red cedar, hemlock, pine (e.g., southern pines), spruce (e.g., black spruce), combinations thereof, and so forth. Exemplary commercially available pulp fibers suitable for the present disclosure include those available from Weyerhaeuser Co. of Federal Way,

Washington under the designation “Weyco CF-405.” Hardwood fibers, such as eucalyptus, maple, birch, aspen, and so forth, can also be used. In certain instances, eucalyptus fibers may be particularly desired to increase the softness of the web. Eucalyptus fibers can also enhance the brightness, increase the opacity, and change the pore structure of the web to increase its wicking ability. Moreover, if desired, secondary fibers obtained from recycled materials may be used, such as fiber pulp from sources such as, for example, newsprint, reclaimed paperboard, and office waste. Further, other natural fibers can also be used in the present disclosure, such as abaca, sabai grass, milkweed floss, pineapple leaf, and so forth. In addition, in some instances, synthetic fibers can also be utilized.

[0034] Besides or in conjunction with pulp fibers, the absorbent material may also include a superabsorbent that is in the form fibers, particles, gels, etc. Generally speaking, superabsorbents are water-swellaable materials capable of absorbing at least about 20 times their weight and, in some cases, at least about 30 times their weight in an aqueous solution containing 0.9 weight percent sodium chloride. The superabsorbent may be formed from natural, synthetic and modified natural polymers and materials. Examples of synthetic superabsorbent polymers include the alkali metal and ammonium salts of poly(acrylic acid) and poly(methacrylic acid), poly(acrylamides), poly(vinyl ethers), maleic anhydride copolymers with vinyl ethers and alpha-olefins, poly(vinyl pyrrolidone), poly(vinylmorpholinone), poly(vinyl alcohol), and mixtures and copolymers thereof. Further, superabsorbents include natural and modified natural polymers, such as hydrolyzed acrylonitrile-grafted starch, acrylic acid grafted starch, methyl cellulose, chitosan, carboxymethyl cellulose, hydroxypropyl cellulose, and the natural gums, such as alginates, xanthan gum, locust bean gum and so forth. Mixtures of natural and wholly or partially synthetic superabsorbent polymers may also be useful in the present disclosure. Particularly suitable superabsorbent polymers are HYSORB 8800AD (BASF of Charlotte, N.C. and FAVOR SXM 9300 (available from Degussa Superabsorber of Greensboro, N.C.).

[0035] The absorbent material typically constitutes from about 20 wt. % to about 95 wt. %, in some implementations from 40 wt. % to about 90 wt. %, and in some implementations, from about 60 wt. % to about 85 wt. % of the composite matrix. Likewise, the synthetic fibers may constitute from about 1 wt. % to about 70 wt. %, in some implementations from 4 wt. % to about 60 wt. %, and in some implementations, from about 5 wt. % to about 50 wt. % of the composite

matrix. The coform web may be formed using a variety of different techniques as is known in the art.

[0036] Referring to FIG. 1, a diagram of an example apparatus 10 for forming a coform nonwoven web is shown, according to some implementations. Generally speaking, the apparatus 10 employs at least one meltblown die head (e.g., two) that is arranged near a chute through which the absorbent material is added while the web forms. As illustrated, the apparatus 10 may include a pellet hopper 12 or 12' of an extruder 14 or 14', respectively, into which a thermoplastic composition may be introduced to form the synthetic fibers of the web. In some implementations, extruders 14 and 14' each have an extrusion screw (not shown), which is driven by a conventional drive motor (not shown). As the thermoplastic composition advances through extruders 14 and 14', it is progressively heated to a molten state due to rotation of the extrusion screw by the drive motor. Heating may be accomplished in a plurality of discrete steps with its temperature being gradually elevated as it advances through discrete heating zones of extruders 14 and 14' toward two meltblowing dies 16 and 18, respectively. Meltblowing dies 16 and 18 may be yet another heating zone where the temperature of the thermoplastic composition is maintained at an elevated level for extrusion.

[0037] When two or more meltblowing die heads are used, such as described above, it should be understood that the fibers produced from the individual die heads may be different types of fibers. That is, one or more of the size, shape, or polymeric composition may differ, and furthermore the fibers may be monocomponent or multicomponent fibers. For example, larger fibers may be produced by the first meltblowing die head, such as those having an average diameter of about 10 micrometers or more, in some implementations about 15 micrometers or more, and in some implementations, from about 20 to about 50 micrometers, while smaller fibers may be produced by the second die head, such as those having an average diameter of about 10 micrometers or less, in some implementations about 7 micrometers or less, and in some implementations, from about 2 to about 6 micrometers. In addition, it may be desirable that each die head extrude approximately the same amount of polymer such that the relative percentage of the basis weight of the coform nonwoven web material resulting from each meltblowing die head is substantially the same.

[0038] Alternatively, it may also be desirable to have the relative basis weight production skewed, such that one die head or the other is responsible for the majority of the coform web in terms of basis weight. As a specific example, for a meltblown fibrous nonwoven web material having a basis weight of 1.0 ounces per square yard or “osy” (34 grams per square meter or “gsm”), it may be desirable for the first meltblowing die head to produce about 30 percent of the basis weight of the meltblown fibrous nonwoven web material, while one or more subsequent meltblowing die heads produce the remainder 70 percent of the basis weight of the meltblown fibrous nonwoven web material. Generally speaking, the overall basis weight of the coform nonwoven web is from about 10 gsm to about 350 gsm, and more particularly from about 17 gsm to about 200 gsm, and still more particularly from about 25 gsm to about 150 gsm.

[0039] Each meltblowing die 16 and 18 is configured so that two streams of attenuating gas per die converge to form a single stream of gas which entrains and attenuates molten threads 20 as they exit small holes or orifices 24 in each meltblowing die. Molten threads 20 are formed into fibers or, depending upon the degree of attenuation, microfibers, of a small diameter which is usually less than the diameter of orifices 24. Thus, each meltblowing die 16 and 18 has a corresponding single stream of gas 26 and 28 containing entrained thermoplastic polymer fibers. Gas streams 26 and 28 containing polymer fibers are aligned to converge at an impingement zone 30. Typically, meltblowing die heads 16 and 18 are arranged at a certain angle with respect to the forming surface, such as described in U.S. Pat. Nos. 5,508,102 and 5,350,624 to Georger et al. For example, meltblown dies 16 and 18 may be oriented at an angle as measured from a plane tangent to the two dies 16 and 18. Typically, each die 16 and 18 is set at an angle ranging from about 30 to about 75 degrees (°), in some implementations from about 35° to about 60°, and in some implementations from about 45° to about 55°. Dies 16 and 18 may be oriented at the same or different angles. In fact, the texture of the coform web may be enhanced by orienting one die at an angle different than another die.

[0040] An absorbent material 32 (e.g., pulp fibers) is added to the two streams 26 and 28 of thermoplastic polymer fibers 20, and at impingement zone 30. Introduction of absorbent material 32 into the two streams 26 and 28 of thermoplastic polymer fibers 20 is desirably gradual in nature. This may be accomplished by merging a secondary gas stream 34 containing absorbent material 32 between the two streams 26 and 28 of thermoplastic polymer fibers 20 so

that all three gas streams converge in a controlled manner. Because they remain relatively tacky and semi-molten after formation, meltblown fibers 20 may simultaneously adhere and entangle with absorbent material 32 upon contact therewith to form a coherent nonwoven structure.

[0041] Any conventional equipment may be employed to supply the absorbent material. In the illustrated implementation, for instance, a picker roll 36 arrangement is provided that has a plurality of teeth 38 adapted to separate a mat or batt 40 of the absorbent material into individual fibers. When employed, the sheets or mats 40 are fed to picker roll 36 by a roller arrangement 42. After the teeth 38 of picker roll 36 have separated the mat into separate fibers, they are conveyed toward the stream of thermoplastic polymer fibers through a nozzle 44. A housing 46 encloses picker roll 36 and provides a passageway or gap 48 between housing 46 and the surface of the teeth 38 of picker roll 36. A gas (e.g., air) is supplied to the passageway or gap 46 between the surface of picker roll 36 and housing 48 by way of a gas duct 50. Gas duct 50 may enter the passageway or gap 46 at junction 52 of nozzle 44 and gap 48. The gas is supplied in sufficient quantity to serve as a medium for conveying absorbent material 32 through nozzle 44. The gas supplied from duct 50 also serves as an aid in removing any remaining absorbent material 32 from the teeth 38 of picker roll 36. The gas may be supplied by any conventional arrangement such as, for example, an air blower (not shown).

[0042] Absorbent material 32 is typically conveyed through nozzle 44 at about the velocity at which absorbent material 32 leaves the teeth 38 of picker roll 36. In other words, absorbent material 32, upon leaving the teeth 38 of picker roll 36 and entering nozzle 44, generally maintains its velocity in both magnitude and direction from the point where they left the teeth 38 of picker roll 36. Such an arrangement, which is discussed in more detail in U.S. Pat. No. 4,100,324 to Anderson, et al. If desired, the velocity of secondary gas stream 34 may be adjusted to achieve coform structures of different properties. For example, when the velocity of secondary gas stream 34 can be adjusted so that it is greater than the velocity of each stream 26 and 28 of thermoplastic polymer fibers 20 upon contact at impingement zone 30, absorbent material 32 is incorporated in the coform nonwoven web in a gradient structure. That is, absorbent material 32 has a higher concentration between the outer surfaces of the coform nonwoven web than at the outer surfaces. On the other hand, when the velocity of secondary gas stream 34 is less than the velocity of each stream 26 and 28 of thermoplastic polymer fibers 20

upon contact at impingement zone 30, absorbent material 32 is incorporated in the coform nonwoven web in a substantially homogenous fashion. That is, the concentration of the absorbent material is substantially the same throughout the coform nonwoven web. This is because the low-speed stream of absorbent material is drawn into a high-speed stream of thermoplastic polymer fibers to enhance turbulent mixing which results in a consistent distribution of the absorbent material.

[0043] To convert composite stream 56 of thermoplastic polymer fibers 20 and absorbent material 32 into a coform nonwoven structure 54, a collecting device may be located in the path of composite stream 56. The collecting device may be a forming surface 58 (e.g., belt, drum, wire, fabric, etc.) driven by rollers 60 and that is rotating as indicated by the arrow 62 in FIG. 1. The merged streams of thermoplastic polymer fibers and absorbent material are collected as a coherent matrix of fibers on the surface of forming surface 58 to form coform nonwoven web 54. If desired, a vacuum box (not shown) may be employed to assist in drawing the near-molten meltblown fibers onto forming surface 58. The resulting textured coform structure 54 is coherent and may be removed from forming surface 58 as a self-supporting nonwoven material.

[0044] It should be understood that the present disclosure is by no means limited to the above-described implementations. In an alternative implementation, for example, first and second meltblowing die heads may be employed that extend substantially across a forming surface in a direction that is substantially transverse to the direction of movement of the forming surface. The die heads may likewise be arranged in a substantially vertical disposition, i.e., perpendicular to the forming surface, so that the thus-produced meltblown fibers are blown directly down onto the forming surface. Such a configuration is well known in the art and described in more detail in, for instance, U.S. Patent Application Publication No. 2007/0049153 to Dunbar, et al. Furthermore, although the above-described implementations employ multiple meltblowing die heads to produce fibers of differing sizes, a single die head may also be employed. An example of such a process is described, for instance, in U.S. Patent Application Publication No. 2005/0136781 to Lassiq, et al.

[0045] The nonwoven laminate may be used in a wide variety of articles. For example, the laminate may be incorporated into an “absorbent article” that is capable of absorbing water or other fluids. Examples of some absorbent articles include, but are not limited to, personal care

absorbent articles, such as diapers, training pants, absorbent underpants, incontinence articles, feminine hygiene products (e.g., sanitary napkins), swimwear, baby wipes, mitt wipe, and so forth; medical absorbent articles, such as garments, fenestration materials, underpads, bedpads, bandages, absorbent drapes, and medical wipes; food service wipers; clothing articles; pouches, and so forth. Materials and processes suitable for forming such articles are well known to those skilled in the art.

[0046] In one particular implementation of the present disclosure, the nonwoven laminate is used to form a wipe. The wipe may be formed entirely from the laminate or it may contain other materials, such as films, nonwoven webs (e.g., spunbond webs, meltblown webs, carded web materials, other coform webs, airlaid webs, etc.), paper products, and so forth. In one implementation, for example, two layers of material may be attached together to form the wipe, such as described in U.S. Patent Application Publication No. 2007/0065643 to Kopacz. In such implementations, one or both of the layers may be formed from the laminate of the present disclosure. In another implementation, it may be desired to provide a certain amount of separation between a user's hands and a moistening or saturating liquid that has been applied to the wipe, or, where the wipe is provided as a dry wiper, to provide separation between the user's hands and a liquid spill that is being cleaned up by the user. In such cases, an additional nonwoven web or film may be attached to a surface of the laminate to provide physical separation and/or provide liquid barrier properties. Other fibrous webs may also be included to increase absorbent capacity, either for the purposes of absorbing larger liquid spills, or for the purpose of providing a wipe with a greater liquid capacity. When employed, such additional materials may be attached to the laminate using any method known to one skilled in the art, such as by thermal or adhesive lamination or bonding with the individual materials placed in face-to-face contacting relation. Regardless of the materials or processes utilized to form the wipe, the basis weight of the wipe is typically from about 20 to about 200 grams per square meter (gsm), and in some implementations, between about 35 to about 100 gsm. Lower basis weight products may be particularly well suited for use as light-duty wipes, while higher basis weight products may be better adapted for use as industrial wipes.

[0047] The wipe may assume a variety of shapes, including but not limited to, generally circular, oval, square, rectangular, or irregularly shaped. Each individual wipe may be arranged

in a folded configuration and stacked one on top of the other to provide a stack of wet wipes. Such folded configurations are well known to those skilled in the art and include c-folded, z-folded, quarter-folded configurations and so forth. For example, the wipe may have an unfolded length of from about 2.0 to about 80.0 centimeters, and in some implementations, from about 10.0 to about 25.0 centimeters. The wipes may likewise have an unfolded width of from about 2.0 to about 80.0 centimeters, and in some implementations, from about 10.0 to about 25.0 centimeters. The stack of folded wipes may be placed in the interior of a container, such as a plastic tub, to provide a package of wipes for eventual sale to the consumer. Alternatively, the wipes may include a continuous strip of material that has perforations between each wipe, and which may be arranged in a stack or wound into a roll for dispensing. Various suitable dispensers, containers, and systems for delivering wipes are described in U.S. Pat. No. 5,785,179 to Buczwinski, et al.; U.S. Pat. No. 5,964,351 to Zander; U.S. Pat. No. 6,030,331 to Zander; U.S. Pat. No. 6,158,614 to Haynes, et al.; U.S. Pat. No. 6,269,969 to Huang, et al.; U.S. Pat. No. 6,269,970 to Huang, et al.; and U.S. Pat. No. 6,273,359 to Newman, et al.

[0048] In certain implementations of the present disclosure, the wipe is a “wet” or “premoistened” wipe in that it contains a liquid solution for cleaning, disinfecting, sanitizing, etc. The particular liquid solutions are not critical and are described in more detail in U.S. Pat. No. 6,440,437 to Krzysik, et al.; U.S. Pat. No. 6,028,018 to Amundson, et al.; U.S. Pat. No. 5,888,524 to Cole; U.S. Pat. No. 5,667,635 to Win, et al.; and U.S. Pat. No. 5,540,332 to Kopacz, et al. The amount of the liquid solution employed may depend upon the type of wipe material utilized, the type of container used to store the wipes, the nature of the cleaning formulation, and the desired end-use of the wipes. Notably, it has been discovered that the laminate of the present disclosure can employ even lower amounts of solution than conventionally employed. For example, each wipe may contain from about 100 wt. % to about 500 wt. %, in some implementations from about 200 wt. % to about 450 wt. %, and in some implementations, from about 250 to about 400 wt. % of a liquid solution based on the dry weight of the wipe.

Surface Winding

[0049] Referring now to FIG. 2, a diagram of a surface winder 200 configured to wind nonwoven web is shown, according to some implementations. In particular, surface winder 200 may be configured to wind a coform nonwoven web or other nonwoven web produced using the

apparatus 10 and/or techniques described above with respect to FIG. 1, or any other type of coform nonwoven web. In some implementations, surface winder 200 is part of a greater coform nonwoven web production system, e.g., including the apparatus 10 and/or techniques described above. For example, surface winder 200 may be positioned at an end of a coform nonwoven web production line in order to wind the produced coform nonwoven web into rolls for later use, e.g., to be transported to another production line or system for manufacturing products (e.g., wipes) from the coform nonwoven web.

[0050] Generally, a surface winder – also referred to as a roll winder or simply winder – is a machine used to wind materials into rolls or spools. Specifically, surface winders are configured to wind a continuous sheet or web of material (e.g., nonwoven web) onto a roll in a controlled manner. As the material (e.g., nonwoven web) is wound onto the roll, it is subjected to tension or pull, which helps maintain the integrity of the wound roll and ensures proper alignment and tightness of the layers. In the context of surface winders, “draw” refers to the pulling force or tension applied to a material being wound onto a roll or spool. Draw is typically defined by a combination of factors, including but not limited to the winding speed, the diameter of the roll being wound, and (optionally) a tension control system, and is generally represented as a percentage (e.g., a “percent draw” or “% draw”). As discussed in greater detail below, surface winders are typically operated at a constant winding speed and thereby a constant draw; however, the present disclosure contemplates a technique of controlling a surface winder to vary the draw throughout the winding of a material (e.g., nonwoven web) into a roll, e.g., by controlling the winding speed.

[0051] As shown, surface winder 200 generally includes at least one winding drum 202 for winding a coform nonwoven web 204 onto a first core 206. Winding drum 202 is a “driven” or powered drum; in other words, winding drum 202 is generally coupled (e.g., directly, through a gear system, by a belt, etc.) to a motor – e.g., an electric motor, as described below – that can be controlled to cause winding drum 202 to rotate. In particular, a speed of the motor can be controlled to adjust a rotational speed of winding drum 202, thereby controlling a speed at which winding drum 202 winds coform nonwoven web 204 onto first core 206. Thus, it will be appreciated that controlling the rotational speed of winding drum 202 can, in turn, be controlled by adjusting or setting the draw of the surface winder 200 (e.g., the draw as coform nonwoven

web 204 is wound onto first core 206). As discussed in greater detail below, controlling the speed of winding drum 202 can also adjust a tension on coform nonwoven web 204, which affects how tightly coform nonwoven web 204 is wound.

[0052] During operations, coform nonwoven web 204 is generally routed across winding drum 202 such that one side of coform nonwoven web 204 is in contact with a portion of the outer surface of winding drum 202. For example, coform nonwoven web 204 may be routed over the top of winding drum 202, as shown in FIG. 2, or underneath winding drum 202. In addition, a portion of the outer surface of winding drum 202 may initially be in contact with an outer surface of first core 206. In other words, first core 206 may be loaded against winding drum 202 such that first core 206 rotates in conjunction with winding drum 202. As winding drum 202 rotates against first core 206 – thereby transferring rotational energy to first core 206 to cause first core 206 to rotate – coform nonwoven web 204 is wound about first core 206 to form first roll 210, e.g., due to the nip principle. In this regard, after an initial layer of coform nonwoven web 204 is wound about first core 206, the outer surface of winding drum 202 may then contact an outer surface of first roll 210 (e.g., coform nonwoven web 204), therefore rotating against the outer surface of first roll 210 and causing first roll 210 to rotate in order to wind coform nonwoven web 204.

[0053] In some implementations, surface winder 200 can include more than one winding drum, e.g., in addition to winding drum 202. In the example of FIG. 2, surface winder 200 may include at least a second winding drum 214, also called a “first position” winding drum. In some implementations, second winding drum 214 is also driven or powered, e.g., by an electric motor. For example, second winding drum 214 may be powered by the same motor as winding drum 202 or by a different/separate motor. In some implementations, winding drum 202 is rotated at least partially in conjunction with second winding drum 214. For example, winding drum 202 may be connected to winding drum 202 directly, through a belt or series of belts, through a gear train, etc. In FIG. 2, for example, winding drum 202 is shown to be coupled to second winding drum 214 via a belt, such that rotation of second winding drum 214 causes winding drum 202 to rotate, or vice versa.

[0054] In some implementations, surface winder 200 can include a carriage 218 that can hold first core 206. In some implementations, carriage 218 can hold more than one core, and thereby

more than one roll of coform nonwoven web. As shown, for example, surface winder 200 can include at least a second core 208 around which a second roll 212 of coform nonwoven web 204 is wound. In some implementations, second roll 212 is formed prior to first roll 210 and then transfer/moved away from winding drum 202 in order to make room for first core 206 and thereby the formation of first roll 210. In this way, second roll 212 can be accessed without interrupting the winding of first roll 210. For example, second roll 212 can be removed from surface winder 200 and transported to another location while first roll 210 is being wound.

Constant Draw Winding

[0055] As mentioned above, coform nonwoven web 204 may be used in a wide variety of articles. For example, the coform nonwoven web 204 may be incorporated into an “absorbent article” that is capable of absorbing water or other fluids (e.g., diapers, training pants, absorbent underpants, incontinence articles, feminine hygiene products, etc.). In some implementations, as also mentioned above, coform nonwoven web 204 is used to produce wipes, such as wet wipes. However, as mentioned above, variability in the thickness of coform nonwoven web 204 due to the winding process, e.g., of surface winder 200, can cause significant issues when producing products downstream (e.g., “converting”). For example, through-roll coform thickness variability in moist wipe production can cause stacker crashes, pouch wrapper jams, lid misplacement, and numerous other problems across various coform converting assets.

[0056] Generally, the thickness of coform nonwoven web (e.g., coform nonwoven web 204) is affected by two main variables – a weight (e.g., due to the number layers) of the coform nonwoven web on the roll and a tension on the coform nonwoven web during winding. Typically, the winding drum(s) of conventional surface winders are operated at a constant speed – and thereby a constant draw – such that tension on the coform nonwoven web is consistent through the winding process (e.g., across each layer of a roll). However, this can cause the inner layers of the roll (e.g., roll 210) to be compressed due to the weight of the outer layers of material, e.g., as the roll reaches its full size. Thus, the inner layers of a roll of coform nonwoven web are typically thinner than the outer layers. In other words, the inner layers of the roll of coform nonwoven web are compressed due to the weight of the outer layers, reducing their thickness; however, the outer layers of the roll are not affected in the same manner.

[0057] FIG. 3 shows an example graph illustrating the effects of this variability in coform nonwoven web thickness throughout a roll when the material is converted into a product, such as a wipe. Specifically, FIG. 3 illustrates stack height variability across multiple stacks of coform nonwoven web sheets, which are produced (e.g., cut) from a roll of coform nonwoven web (e.g., to form wipes) that was wound at a constant draw, according to some implementations. In this example, it is shown that the height of a stack of n sheets of coform nonwoven web is generally greatest when the stack of n sheets are produced from the outer layers of a roll of coform nonwoven web (e.g., first roll 210). In contrast, the height of a stack of n sheets of coform nonwoven web produced from the inner layers of a roll is much shorter – in this example, around 0.6 inches thinner. Thus, it will be understood that a stack of coform nonwoven web sheets produced from the outer layers of a roll is generally significantly taller than a stack of coform nonwoven web sheets produced from the inner layers of the roll due to variability in the thickness of coform nonwoven web throughout the roll. In other words, the coform nonwoven web is generally thickest at the outer-most layers of the roll and thinnest at the inner-most layers of the roll.

[0058] The effects of variability in the thickness of coform nonwoven web throughout a roll (e.g., “through-roll thickness”) are further illustrated in FIG. 4A, which shows a graph that overlays stack height and roll diameter for a series of example coform nonwoven web rolls. In particular, the graph of FIG. 4A compares stack height and roll diameter – shown as stack height data 402 and roll diameter line 404, respectively – over three example rolls of coform nonwoven web produced using a constant winder draw profile. As described herein, a “constant winder draw profile” generally refers to a control method for the winding drum(s) of a surface winder (e.g., winding drum 202 of surface winder 200) in which the winding drum(s) are operated at a constant speed (e.g., corresponding to a constant draw) throughout the winding of a roll. In other words, the example rolls represented by the graph in FIG. 4A were produced by operating a surface winder at a constant draw throughout the production (e.g., winding) of each roll. Each roll was then transferred to a coform converting asset (e.g., a different production line/system) for producing stacks of wipes, e.g., for wet wipe production, and the resulting stack heights of n sheets of the coform nonwoven web were measured.

[0059] As shown, stack height (e.g., shown as stack height data 402) generally decreases in conjunction with roll diameter, which aligns with the results presented in FIG. 3. In other words, sheets produced from coform nonwoven web closer to the center of the roll are generally thinner than sheets produced from coform nonwoven web closer to an outside of the roll. When multiple sheets are stacked, this effect compounds, resulting in significantly different stack heights for stacks of n sheets depending on which portion of a roll the sheets were produced from. Thus, FIGS. 3 and 4A clearly demonstrate how variability in the thickness of a coform nonwoven web due to winding at a constant draw can ultimately impact the quality of a produced article and/or can cause numerous issues in the production of various articles from a roll of coform nonwoven web. Additional discussion of an example system for converting a roll of nonwoven web into stacks of sheets is provided below with respect to FIGS. 10A-11B.

Variable Draw Winding

[0060] As mentioned above, the present disclosure generally relates to a method, and related systems and devices, that address variability in coform nonwoven web thickness due to winding by varying the draw of a surface winder (e.g., surface winder 200) as the coform nonwoven web is wound into a roll. Details of the winding method are provided below with respect to FIGS. 5-9; however, at a high level, the surface winder (e.g., surface winder 200) is generally operated by periodically and repeatedly: i) increasing a draw by a first magnitude; ii) maintaining the increased draw until the diameter of the roll increases by a first predetermined amount; iii) decreasing the draw by a second magnitude; and iv) maintaining the decreased draw until the diameter of the roll increases by a second predetermined amount. Generally, the second magnitude is less than the first magnitude such that the “increased draw” and the “decreased draw” both increase with each periodic increase/decrease of the draw. Herein, this periodic increase and decrease of draw may be referred to as a “variable winder draw profile,” illustrated in FIGS. 6 and 7 and described below.

[0061] As mentioned above with respect to FIG. 2, draw is typically defined by a combination of factors, including winding speed, roll diameter, and applied tension to the material. It will be appreciated, however, that roll diameter is generally variable throughout the winding process (e.g., the diameter of a roll inherently increases through winding) and that not all surface winding machines include a variable tension adjustment system. Thus, as described herein, draw is

typically controlled (e.g., set) by varying winder drum speed, and thereby by the winding speed of a material (e.g., coform nonwoven web 204) into a roll. In particular, the speed of winding drum 202 may be increased to correspondingly increase the draw and decreased to correspondingly decrease the draw, or vice versa.

[0062] FIG. 4B shows a graph that overlays stack height and roll diameter for coform nonwoven web produced using the above-mentioned variable winder draw profile, according to some implementations. Like the graph of FIG. 4A, the graph shown in FIG. 4B was generated by producing three example rolls of a coform nonwoven material; however, the rolls represented by FIG. 4B were wound using the above-mentioned variable winder draw profile. As shown, this results in a much more consistent through-roll thickness which in turn results in a more consistent stack height (e.g., shown as stack height data 402) for produced sheets. In other words, the height of a stack of n sheets of the coform nonwoven material was relatively consistent regardless of which portion of the roll (e.g., the center or outside layers) the sheets were produced from.

[0063] As described herein, this repeated and periodic increasing and decrease of draw winds the coform nonwoven web in a distinct manner that imparts a compression relief layer in the roll every n inches to create a “cushion,” providing a more constant through-roll thickness of the coform nonwoven web by preventing each layer of the roll from compressing all the layers under it as the diameter of the roll expands. In addition, gradually increasing the draw (e.g., where each increased and decreased draw value is greater than a most recent increased or decreased draw value, respectively) causes a gradual increase in the tension at which the coform nonwoven web is wound, as shown in FIG. 6 below, such that outer layers are wound at an increased tension with respect to inner layers. As shown in FIG. 4B, this can result in more even thickness of the coform nonwoven web through a roll, as increased tension can cause a decrease in thickness of the coform nonwoven web. Thus, the outer layers of the roll can be wound at an increased tension such that their thickness more closely matches the inner layers of the roll, which are impacted by the weight of the roll itself. In other words, the outer layers can be made thinner to more closely match the thickness of the inner layers. Additional discussion of stack height variability between stacks of sheets produced using rolls of nonwoven web that were

wound using constant and variable draw profiles, and related testing results, is provided below with respect to FIGS. 12 and 13.

System and Methods for Variable Draw Winding

[0064] Referring now to FIG. 5, a block diagram of a system 500 for producing rolls of coform nonwoven web is shown, according to some implementations. System 500 is shown to include surface winder 200, as described above, which includes winding drum 202 and first core 206. As described above, surface winder 200 can include a motor 216 for rotating winding drum 202. In some implementations, motor 216 is an electric motor. Surface winder 200 may further include a carriage 218 or components for holding first core 206, e.g., as roll 210 is created. In some implementations, surface winder 200 can also include second roll 212 and/or second winding drum 214 and therefore may include a second carriage for holding second core 208 during the production of second roll 212. In some implementations, where surface winder 200 includes more than one winding drum (e.g., second winding drum 214), surface winder 200 can further include more than one motor (e.g., more than one of motor 216). Alternatively, as mentioned above, motor 216 can be configured to operate (e.g., rotate) both winding drum 202 and second winding drum 214.

[0065] In some implementations, surface winder 200 also includes a roll thickness sensor 220 for measuring a diameter of the roll of coform nonwoven web (e.g., first roll 210) as it is being produced (e.g., wound). Generally, roll thickness sensor 220 may be any suitable sensor for measuring the diameter of a roll. In some implementations, roll thickness sensor 220 is a laser sensor, or similar, for measuring a distance between a fixed mounting point and the surface of the roll. Based on the distance to the surface of the roll, controller 510 can calculate a roll diameter. In other implementations, another type of sensor can be used to measure roll diameter. Notably, the diameter of the roll may be periodically or continuously measured throughout winding.

[0066] System 500 is further shown to include a controller 510 for controlling the operations of surface winder 200. In particular, controller 510 may transmit control signals to and/or receive signals/data from various components of surface winder 200, as described in greater detail below. Controller 510 is shown to include a processor 512 and memory 514. Processor 512 can be a general-purpose processor, an application-specific integrated circuit (ASIC), one or

more field programmable gate arrays (FPGAs), a group of processing components, or other suitable electronic processing structures. In some implementations, processor 512 is configured to execute program code stored on memory 514 to cause controller 510 to perform one or more operations, as described below in greater detail. In some implementations, processor 512 and memory 514 can be communicably connected, such as via a processing circuit, and can include computer code for executing (e.g., by processor 512) one or more processes described herein.

[0067] Memory 514 can include one or more devices (e.g., memory units, memory devices, storage devices, etc.) for storing data and/or computer code for completing and/or facilitating the various processes described in the present disclosure. In some implementations, memory 514 includes tangible (e.g., non-transitory), computer-readable media that stores code or instructions executable by processor 512. Tangible, computer-readable media refers to any physical media that is capable of providing data that causes controller 510 to operate in a particular fashion. Example tangible, computer-readable media may include, but is not limited to, volatile media, non-volatile media, removable media and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Accordingly, memory 514 can include RAM, ROM, hard drive storage, temporary storage, non-volatile memory, flash memory, optical memory, or any other suitable memory for storing software objects and/or computer instructions. Memory 514 can include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure.

[0068] While shown as individual components, it will be appreciated that processor 512 and/or memory 514 can be implemented using a variety of different types and quantities of processors and memory. For example, processor 512 may represent a single processing device or multiple processing devices. Similarly, memory 514 may represent a single memory device or multiple memory devices. Additionally, in some implementations, controller 510 may be implemented within a single computing device (e.g., one server, one housing, etc.). In other implementations, controller 510 may be distributed across multiple servers or computers (e.g., that can exist in distributed locations). For example, controller 510 may include multiple distributed computing devices (e.g., multiple processors and/or memory devices) in communication with each other that

collaborate to perform operations. For example, but not by way of limitation, an application may be partitioned in such a way as to permit concurrent and/or parallel processing of the instructions of the application. Alternatively, the data processed by the application may be partitioned in such a way as to permit concurrent and/or parallel processing of different portions of a data set by two or more computers.

[0069] It will also be appreciated that, in implementations where controller 510 is part of another computing device (e.g., a control system for a larger coform nonwoven production line), the components of controller 510 may be shared with, or the same as, the host device. In some implementations, controller 510 is a programmable logic controller (PLC). For example, controller 510 may be one of one or more PLCs that control operations of a coform nonwoven web production system (e.g., including the various components described above with respect to FIGS. 1 and/or 2). In some implementations, controller 510 is implemented via multiple PLCs.

[0070] Controller 510 is also shown to include a communications interface 516 that facilitates communications between controller 510 and any external components or devices. For example, communications interface 516 can provide means for transmitting data to and/or receiving data from a remote computing device, e.g., for programming controller 510. Accordingly, communications interface 516 can be or can include a wired or wireless communications interface (e.g., jacks, antennas, transmitters, receivers, transceivers, wire terminals, etc.) for conducting data communications, or a combination of wired and wireless communication interfaces. In some implementations, communications via communications interface 516 are direct (e.g., local wired or wireless communications) or via a network (e.g., a WAN, the Internet, a cellular network, etc.). For example, communications interface 516 may include one or more Ethernet ports for communicably coupling controller 510 to a network (e.g., the Internet). In another example, communications interface 516 can include a Wi-Fi transceiver for communicating via a wireless communications network. In yet another example, communications interface 516 may include cellular or mobile phone communications transceivers. In yet another example, communications interface 516 may include a universal serial bus (USB) connection for communicating data to an external device.

[0071] In some implementations, controller 510 includes an input/output (I/O) interface 518 for communicating signals to remote devices. In some such implementations, I/O interface 518

is configured to facilitate the sending and receiving of signals from/to the components of surface winder 200. In particular, I/O interface 518 can facilitate the transmission of control signals to a winding drum motor 216 for controlling the speed of winding drum 202 and/or second winding drum 214. Additionally, I/O interface 518 can facilitate the receipt of signals (e.g., data) from roll thickness sensor 220 or other components of surface winder 200. Accordingly, I/O interface 518 can be configured to communicate (e.g., send and/or receive) digital and/or analog signals. For example, in some implementations, controller 510 outputs digital signals to control relays for providing/controlling power to motor 216. In some implementations, controller 510 controls the speed of winding drum 202 by sending and/or receiving signals to/from a variable-frequency drive (VFD), which interprets the signals from controller 510 and controls motor 216 directly.

[0072] As mentioned above, draw is generally defined as a percentage value (e.g., “% draw”) and is determined by multiple factors, including winding speed. To this point, controller 510 is generally configured to variably adjust draw during winding of coform nonwoven web 204 into a roll, based on the variable winder draw profile mentioned above, by controlling the speed of motor 216. Specifically, controller 510 can periodically increase and subsequently decrease the speed of motor 216 to correspondingly increase and subsequently decrease the draw in a positive-sloped stair-step (or sinewave-like) pattern, as illustrated in FIGS. 6 and 7. In some implementations, the variable winder draw profile is predefined (e.g., stored in memory 514). For example, controller 510 may be programmed (e.g., by a remote device) such that a variable winder draw profile, as described herein, is stored in memory 514.

[0073] In some implementations, the variable winder draw profile may be stored as an array or in a lookup table. For example, the variable winder draw profile may be stored in an array that associates (e.g., maps) a roll diameter with a draw value (e.g., represented as a percentage). In some such implementations, the array further associates a roll diameter to a winding drum speed such that controller 510 operates motor 216 at a specific speed dependent on a current diameter of the roll of coform nonwoven web. Alternatively, in some such implementations, a draw value associated with a given roll diameter can be used (e.g., by controller 510) to determine a winding speed, which is then used to control winding drum 202. In other implementations, the variable winder draw profile is stored as one or more equations for calculating a draw value based on a diameter of the roll. For example, controller 510 may calculate a draw value in real or near-real

time based on a measured diameter of the roll, and the draw value can in turn be used to calculate a speed at which to operate winding drum 202. In some such implementations, the diameter of the roll may be a variable in each equation. In either case, controller 510 may be configured to monitor (e.g., periodically or continuously measure) a diameter of the roll (e.g., roll 210) throughout winding to determine the draw.

[0074] As described above, controller 510 is generally configured to periodically vary the draw, e.g., by varying the speed of winding drum 202. For example, varying the speed of the winding drum 202 may, in some implementations, be achieved by controlling motor 216 (for each period) to include: i) increasing the draw by a first magnitude, which in turn increases the speed of the winding drum 202; ii) maintaining operations of winding drum 202 at the increased speed until the diameter of the roll increases by a first predetermined amount; iii) decreasing the draw by a second magnitude that is less than the first magnitude, which in turn decreases the speed of the winding drum 202; and iv) maintaining operations of winding drum 202 at the decreased speed until the diameter of the roll increases by a second predetermined amount. FIG. 6 shows a graph 600 which plots this periodic increase and decrease of the draw as a positive-sloped step waveform draw profile 602, according to some implementations. Specifically, step waveform draw profile 602 generally represents a draw – as defined based on a speed of winding drum 202 – with respect to a diameter of the produced roll of coform nonwoven web (e.g., as determined from measurements by roll thickness sensor 220).

[0075] Also plotted on graph 600 is a representation of the pressure on the coform nonwoven web as it is being wound to create a roll – illustrated as “pressure” line 604 which represents pressure in “pounds per linear inch” or PLI. It can be seen that the pressure on the coform nonwoven web generally increases as the diameter of the roll increases (e.g., in a stair-step pattern). For example, the pressure on the coform nonwoven web is about 1.8 PLI initially, which climbs with each periodic increase/decrease of draw to a final pressure of 3.0 PLI. As mentioned above, winding coform nonwoven web according to the variable draw profile described herein (e.g., represented by step waveform draw profile 602) imparts a compression relief layer in the roll every n inches, as a diameter of the roll increases. This creates a cushion effect, providing a more constant through-roll thickness of the coform nonwoven web by

preventing each layer of the roll from compressing all the layers under it as the diameter of the roll expands.

[0076] With respect to step waveform draw profile 602, controller 510 is shown to operate surface winder 200 at an initial draw value (e.g., 101.24% draw) until a first threshold roll diameter is reached. In the example shown, the initial draw value is maintained until the roll reaches about 14 inches in diameter. Once the first threshold roll diameter is reached, controller 510 increases the draw by a first magnitude (e.g., to 101.99% draw) and maintains operations at the increased draw until the diameter of the roll increases by a first predetermined amount (e.g., four inches). Then, controller 510 decreases the draw by a second magnitude and maintains operations at the decreased draw value until the diameter of the roll increases by a second predetermined amount (e.g., two inches). As mentioned above, increasing the draw generally corresponds to an increase in winding drum speed 202 and decreasing the draw generally corresponds to a decrease in the speed of winding drum 202. In other words, as draw is increased, the speed of winding drum speed 202 increases, and as the draw is decreased, the speed of winding drum speed 202 decreases. As shown, the draw is generally increased by more than it is decreased for each period; thus, step waveform draw profile 602 is shown to generally increase in a linear manner over time. For example, controller 510 may increase the draw by 0.75% and subsequently decrease the draw by 0.72% with each periodic repetition. In this manner, each successive “increased draw” and “decreased draw” may be greater/higher (e.g., by 0.03%) than a previous “increased draw” and “decreased draw.”

[0077] In some implementations, a value of each of the first magnitude and the second magnitude remains constant for each periodic increase and decrease of the draw. In other words, controller 510 may increase the draw by the same magnitude with each periodic increase (e.g., with each repetition) and may decrease the draw by the same magnitude with each periodic decrease. As in the example above, controller 510 may increase the draw by 0.75% with each periodic increase and decrease the draw by 0.72% with each periodic decrease. Thus, as an example, the draw may follow a pattern of: increased by 0.75%, decreased by 0.72%, increased by 0.75%, decreased by 0.72%, ..., and so on.

[0078] In other implementations, a value of one or both of the first magnitude and the second magnitude can be different or variable for each periodic increase and decrease of the draw. In

other words, controller 510 may increase the draw by a different magnitude with each periodic increase (e.g., with each repetition) and/or may decrease the draw by a different magnitude with each periodic decrease. In this case, as an example, the draw could follow a pattern of: increased by 0.75%, decreased by 0.72%, increased by 0.78%, decreased by 0.72%, ..., and so on. Or, as another example: increased by 0.75%, decreased by 0.72%, increased by 0.78%, decreased by 0.68%, ..., and so on.

[0079] FIG. 7 illustrates step waveform draw profile 602 in greater detail, according to some implementations. Specifically, FIG. 7 shows a close-up view of the first three periods of step waveform draw profile 602. As shown, each period of step waveform draw profile 602 is defined by a step-up 702, a peak period 704, a step-down 706, and a valley period 708, which correspond to the increase/decrease of the draw during that period. With respect to the discussion above, each step-up 702 corresponds to an increase in draw by a first magnitude and each step-down 706 corresponds to a decrease in draw by a second magnitude. Generally, the first magnitude is greater than the second magnitude; in other words, each step-up 702 is greater than its respective step-down 706.

[0080] As described herein, each step-up 702 is generally associated with an increase in draw of about 0.75%; however, the magnitude of each step-up 702 may fall anywhere from about 0.02% to about 2%. Each step-down 706 is generally associated with a decrease in draw of about 0.72%; however, the magnitude of each step-down 706 may fall anywhere from about 0.01% to about 2%. As mentioned, each step-up 702 is generally greater in magnitude than each respective step-down 706. For example, if step-up 702 corresponds to an increase in draw of 0.75%, then the magnitude of step-down 706 will be less than 0.75% (e.g., 0.72% in the example of FIG. 7). To this point, each peak period 704 is associated with a higher draw than any previous peaks and each valley 708 is associated with a higher draw than any previous valley. For example, in FIG. 7, a first peak corresponds to a % draw of 101.99, and a second peak corresponds to a % draw of 102.13. Likewise, a first valley corresponds to a % draw of 101.38, and a second peak corresponds to a % draw of 102.18.

[0081] In some implementations, the draw (e.g., of winding drum 202) is maintained at each respective peak period 704 or valley period 708 until a diameter of the roll has increased by a predetermined amount. Specifically, the draw may be maintained at each respective peak period

704 until the diameter of the roll has increased by a first amount and at each respective valley period 708 until the diameter of the roll has increased by a second amount. Generally, the first amount (e.g., the period that the draw is maintained at a peak) is different from the second amount (e.g., the period that the draw is maintained at a valley); however, in some implementations, the first and second amounts may be the same.

[0082] In the example of FIG. 7, the draw is maintained at each respective peak period 704 and valley period 708 until the diameter of the roll has increased by four inches and two inches, respectively. However, it should be appreciated that the present disclosure is not intended to be limiting in this regard. Rather, each peak period 704 and valley period 708 may be maintained until the diameter of the roll has increased by any other predetermined amount. Alternatively, in some implementations, the draw is maintained at each respective peak period 704 and valley period 708 for predetermined periods of time (e.g., as opposed to being maintained based on a diameter of the roll). As shown, in some implementations, the draw is maintained at each peak period 704 for a greater period (e.g., based on time or roll diameter) than for each respective valley period 708; however, in various other implementations, each peak period 704 and valley period 708 can be the same (e.g., can have the same width, when plotted as in FIG. 7) or each peak period 704 can be shorter than its respective valley period 708. Further it should be appreciated that each peak period 704 and valley period 708 may vary in width throughout the processes of producing a roll of coform nonwoven web.

[0083] Referring now to FIG. 8, a flow diagram of a process 800 for producing a roll of nonwoven web is shown, according to some implementations. Specifically, in some implementations, process 800 can be used to produce a roll of coform nonwoven web, e.g., as part of a process of manufacturing the coform nonwoven web. In some implementations, process 800 is partially implemented by controller 510, as described above. However, it should be appreciated that process 800 can be implemented by other devices that can control the operations of a surface winder. It will be appreciated that certain steps of process 800 may be optional and, in some implementations, process 800 may be implemented using less than all of the steps. It will also be appreciated that the order of steps shown in FIG. 8 is not intended to be limiting.

[0084] At step 802, a nonwoven web (e.g., a coform nonwoven web) is fed across a winding drum of a surface winder and onto a core. In particular, the nonwoven web is routed across (e.g., over or under) winding drum such that one side of the nonwoven web is in contact with a portion of the outer surface of the winding drum. In some implementations, the nonwoven web may be fed across the winding drum at an output of a coform nonwoven web production line. For example, the surface winder may be positioned at an end of the coform nonwoven web production line to wind produced coform nonwoven web. As mentioned above, the winding drum of the surface winder may be loaded against a core, e.g., that rotates in conjunction with the winding drum as the winding drum rotates.

[0085] At step 804, the winding drum is operated to cause the nonwoven web to wind around the core, forming a roll. In some implementations, the winding drum is operated by providing power to an electric motor that drives the winding drum to cause the winding drum to rotate. In some implementations, a pulse width modulated (PWM) signal is provided (e.g., by controller 510) to the electric motor to operate the winding drum. In some implementations, rather than directly providing power and/or control signals to a motor for the winding drum (e.g., motor 216), controller 510 provides a setpoint speed or other control instructions/signals to a VFD and the VFD controls the motor and thereby the speed of the winding drum. For example, controller 510 may transmit a speed setpoint to a VFD, which then operates the winding drum motor.

[0086] At step 806, a draw of the winding drum is periodically increased and subsequently decreased as the nonwoven web is wound onto the core to form the roll. In particular, controller 510 can periodically increase the draw by a first magnitude and subsequently decrease the draw by a second magnitude (e.g., in a stair-stepped or sine-wave-like pattern). As mentioned above, this variation in draw coincidentally varies a tension of the nonwoven web during winding. Generally, the second magnitude is less than the first magnitude such that the average draw increases over time; or, rather, as the roll of nonwoven web increases in diameter. In some implementations, the periodic increasing and subsequent decreasing of the draw (e.g., step 806) is repeated until the roll reaches a threshold diameter. Details of this periodic increasing and subsequent decreasing of the draw are provided above with respect to FIGS. 6 and 7.

[0087] In some implementations, the surface winder is operated at an initial draw (e.g., at step 804) until the diameter of the roll reaches an initial threshold, and the periodic increasing and

subsequent decreasing of the draw (e.g., step 806) is initiated after the diameter of the roll reaches the initial threshold. In some implementations, for each periodic increase and decrease of the draw— in other words, for each repetition of step 808 – the draw is maintained at the increased value until a diameter of the roll increases by a first amount and/or at the decreased value until the diameter of the roll increases by a second amount. For example, the draw may be maintained at the increased value until a diameter of the roll increases by four inches and at the decreased value until the diameter of the roll increases by two inches for each repetition of step 808. Accordingly, during step 806, controller 510 may be configured to periodically and/or continuously measure a diameter of the roll (e.g., using roll thickness sensor 220).

[0088] Referring now to FIG. 9, a flow diagram of a process 900 for variably controlling a surface winder based on a step waveform draw profile is shown, according to some implementations. In some implementations, process 900 is a continuation of steps 804 and/or 806 of process 800, as discussed above. In some implementations, process 900 is implemented by controller 510, as described above. However, it should be appreciated that process 900 can be implemented by other devices that can control the operations of a surface winder. It will be appreciated that certain steps of process 900 may be optional and, in some implementations, process 900 may be implemented using less than all of the steps. It will also be appreciated that the order of steps shown in FIG. 9 is not intended to be limiting.

[0089] At step 902, a winding drum (e.g., of a surface winder) is operated at an initial draw until a produced roll of nonwoven web (e.g., a coform nonwoven web) reaches a first diameter. Generally, the initial draw remains constant until the roll of nonwoven web reaches a first diameter. In some implementations, controller 510 determines that the roll has reached the first diameter by measuring a diameter of the roll using one of more sensors (e.g., roll thickness sensor 220). In other implementations, controller 510 infers the diameter of the roll by tracking a number of rotations of the roll and/or the winding drum, and/or by tracking an amount of time that has elapsed since winding of the roll began. As discussed above with respect to step 804 of process 800, in some implementations, the winding drum is operated by providing power to an electric motor that drives the winding drum to cause the winding drum to rotate. In some implementations, a PWM signal is provided (e.g., by controller 510) to the electric motor to operate the winding drum. In some implementations, rather than directly providing power and/or

control signals to a motor for the winding drum (e.g., motor 216), controller 510 provides a setpoint speed or other control instructions/signals to a VFD and the VFD controls the motor and thereby the speed of the winding drum. For example, controller 510 may transmit a speed setpoint to a VFD, which then operates the winding drum motor.

[0090] At step 904, the draw is increased by a first magnitude and maintained at the increased magnitude until the roll reaches a second diameter. In other words, the draw of the winding drum is “stepped-up” to a peak value and maintained at the peak value until the roll reaches the second diameter. In some implementations, the “first magnitude” corresponds to a percentage or an amount relative to a previous draw (e.g., the initial draw) rather than a specific value. For example, the draw may be increased by 0.75% over a previous draw. Likewise, the “second diameter” may be relative to the first diameter. For example, the second diameter may be four inches greater than the first diameter. In some implementations, step 904 includes periodically and/or continuously measuring a diameter of the roll (e.g., using roll thickness sensor 220) to determine when the roll increases to the second diameter.

[0091] At step 906, the draw is decreased by a second magnitude and maintained at the decreased magnitude until the roll reaches a third diameter. In other words, the draw of the winding drum is “stepped-down” to a “valley” value and maintained at the “valley” value until the roll reaches the third diameter. In some implementations, the “second magnitude” corresponds to a percentage or an amount relative to a previous draw (e.g., the increased draw from step 904) rather than a specific value. For example, the draw may be decreased by 0.72% over a previous draw. Generally, as discussed herein, the second magnitude is generally smaller/less than the first magnitude. In other words, each increase in the draw (e.g., step 904) is greater in magnitude than a following decrease in the draw. Likewise, the “third diameter” may be relative to the second diameter. For example, the third diameter may be two inches greater than the first diameter. Like step 904, step 906 may further include periodically and/or continuously measuring a diameter of the roll (e.g., using roll thickness sensor 220) to determine when the roll increases to the third diameter.

[0092] Notably, steps 904 and 906 of process 900 may be repeated (e.g., periodically), at least until the roll of nonwoven web reaches a final diameter. For example, the draw of the surface winder may be increased from the “valley” value to a new peak value and maintained at the new

peak value until the roll reaches a fourth diameter; then, the draw of the surface winder may be decreased from the new peak value to a new “valley” value and maintained at the new “valley” value until the roll reaches a fifth diameter; and so on. As mentioned above, for each repetition of steps 904 and 906, the draw may be increased/decreased relative to a previous or “most recent” draw such that each increased and decreased draw value is greater than a most recent increased or decreased draw value, respectively.

Nonwoven Web Conversion

[0093] As discussed at length above, the disclosed system and methods can help to reduce or eliminate variability in the thickness of a nonwoven web through a roll, which in turn can reduce or eliminate downstream issues (e.g., when converting the roll into a finished product). It will also be appreciated that the rolls of nonwoven web produced using the system and methods described herein (e.g., first roll 210 and/or second roll 212) can be converted into a wide variety of articles. One such type of article briefly discussed above with respect to FIGS. 3, 4A, and 4B, are wipes (e.g., wet wipes). Wipes are generally folded sheets of nonwoven material (e.g., coform nonwoven web 204). Often, wipes are produced in stacks of n folded sheets to be packaged and/or stored. An example system and related methods for producing and stacking sheets of nonwoven web (e.g., for wipes) is described below; however, it will be appreciated that numerous other techniques for producing stacks of sheets of nonwoven materials can be used.

[0094] Referring now to FIGS. 10A-10C, in general, various schematics of a system 1000 for converting nonwoven materials into stacks of sheets are shown, according to some implementations. Starting on the right side of FIG. 10A, a roll 1030 of basesheet material 1031 is shown. In some implementations, the roll 1030 of basesheet material 1031 may comprise a roll of nonwoven material (e.g., first roll 210 and/or second roll 212) formed using the apparatus 10 (e.g., as shown and described in FIG. 1) and the surface winder 200 (e.g., using a variable winder draw profile as shown and described in FIGS. 2-9).

[0095] Generally, roll 1030 can be supported by a roll support 1033. Basesheet material 1031 is fed from roll 30 through a series of advancing rollers such as idler rollers 32 and dancer roller 1034. From there, the web of basesheet material 1031 travels to a slitter assembly 1040. Slitter assembly 1040 can include an anvil roller 1042 and slitting blades 1044 that form weakened lines 1024 (e.g., perforated slitting blades that thereby form perforations 1025) in the

sheet as it travels in machine direction 1038 through slitter assembly 1040. As a result of traveling through slitter assembly 1040, the web is formed into a plurality of panels 1028 joined to adjacent panels along the plurality of weakened lines 1024. Next, the web of basesheet material 1031 travels over an upper idler roller 1046 and over to an arched roller assembly 1050. The web then travels into a folding assembly 1060. Folding assembly 1060 generally includes a series of folding boards 1062 that assist in necking down the web in the cross direction 1039 in a controlled fashion to induce folds in machine direction 1038.

[0096] In some implementations, as the web travels down through folding assembly 1060, a moistening assembly 1070 can apply a liquid (e.g., a lotion or other solution). Moistening assembly 1070 can include a bar 1072 having ports 1074 for imparting liquid or solution onto the moving web as it is necked down into a fan-folded ribbon of material. A liquid or solution can be provided at a desired add-on rate and in a conventional manner to bar 1072 so it can be applied through ports 1074 to the moving web. Such application could include spraying or drooling with bar 1072 or could include alternate structures (not shown) for techniques such as printing, a bath, a flooded nip, or hollowed-out folding boards with spray orifices that project fluid in a rather even horizontal plane as the web moves by the boards. Alternatively, if a dry final product is desired the moistening assembly can be eliminated while the manufacturing apparatus and process could be the same. As the web travels further down folding assembly 1060, the web becomes corrugated to a point where the web is compressed in the cross direction by means of nip rollers 1076. At this point, the web forms a single ribbon of fan-folded sheets that then travels by a conveyor assembly 1080 including a pull roller 1082, support belt 1084, and support rollers 1086 which are an idler roller and a drive roller. The web continues to travel to an adhesive application assembly 1090. Adhesive application assembly 1090 can apply an adhesive 1092 via an adhesive nozzle 1096 to the top of the ribbon, e.g., along an edge. Adhesive can be applied by various techniques known to those of skill in the art.

[0097] The web – now referred to as a “ribbon” – with adhesive applied thereto, travels on to a cutter assembly 1001, which includes a rotary cutter 1002 and anvil roller 1004. The ribbon is then cut into discreet pieces, called clips 1020, which then pass to a stacker assembly 1010. The stacker assembly includes a stacker belt 1012 and stacker rollers 1014, which are an idler roller and a drive roller. In stacker assembly 1010, clips 1020 are stacked one upon the other and

thereby the adhesive 1092 on the top sheet of a clip adheres to a bottom sheet of the subsequent clip that is stacked on top of it. A desired number of clips 1020 are stacked one on top of another and adhesively joined in this manner. Then, the completed stack is moved to a packaging assembly (not shown) where the clips can be put in various types of dispensers (e.g., tubs, bags, etc.) and then made ready for commercial sale and use. Generally, a “stack,” as described herein, includes at least two clips 1020, where each clip includes at least two sheets 1022. In some implementations, the at least two sheets 1022 are separably joined together along a weakened line 1024. Each of the clips 1020 can be separably joined to an adjacent clip, e.g., by the last sheet of one clip being joined to the first sheet of a succeeding clip. In some implementations, stacks of fan-folded material can have any sheet in one clip joined to any sheet in a succeeding clip as long as dispensing of sheets from a preceding clip dispense simultaneously at least one sheet of a succeeding clip so as to continue successive dispensing of the entire stack 1010, as desired.

[0098] As described herein, sheets of material may be considered “separably joined” when each sheet of a plurality, e.g., in a stack of sheets, is engaging any adjacent sheet while in the dispenser or package such that withdrawing the leading sheet through the dispenser or package opening also withdraws at least a portion of the following sheet through the opening before the leading sheet and the following sheet separate completely from each other. Such engaging of any adjacent sheet can include a non-interfolded relationship in combination with one or more of the following between adjacent sheets: adhesive, friction, cohesion, fusion bonding (e.g., ultrasonic welding, heat sealing), mechanical entanglement (e.g., needle punching, steam sealing, embossing, crimping), autogenous bonding, and/or weakened line(s) (e.g., perforations, zones of frangibility, score line(s), crush cutting).

[0099] FIGS. 10B and 10C, in particular, illustrate a portion of arched roller assembly 1050 and folding assembly 1060 in greater detail. Specifically, mounting bars 1065a and 1065b are shown for mounting and positioning the folding boards as desired. Bars 1066 can also be used to assist in aligning the fan-folded material as it exits the folding board area and travels into nip rollers 1076. It will be appreciated that the number of boards 1062 can be readily varied in order to achieve a desired folding pattern. Also, other folding techniques and structures could be

employed, such as using folding blades, folding pins, or other techniques to mechanically push or guide the sheet into a desired folding pattern.

[0100] In FIG. 10B, for example, boards 1062 can be adjustably secured to a conventional mounting mechanism and, as such, boards 1062 mounted by bar 1065a are positioned in the front of the material being fan folded (e.g., and such could be visible in a view like FIG. 10A) and boards 1062 mounted by bar 1065b are positioned in the back of the material being fan folded (e.g., and such could not be visible in a view like FIG. 10A). In this way, a sheet of web material zigzags between the adjacent folding boards as it is folded from a flat sheet near arched roller assembly 1050 into a fan folded configuration beginning at the top of the folding boards nearest arched roller assembly 1050 down to the bottom of the folding board area and nearest nip rollers 1076. In some implementations, to relieve tension on the sheet and/or assist it in passing through the folding assembly 1060, arched roller assembly 1050 can be tilted backward to some degree (e.g., from about 1 degree to about 10 degrees or from about 3 degrees to about 7 degrees or about 5 degrees) from vertical seen at 1058a to backward off vertical seen at 1058b and represented by angle 1058.

[0101] In some implementations, folding boards 1062 are spaced from each other a certain amount in both longitudinal and lateral directions. As the web being fan-folded travels further down folding boards 1062 and towards nip rollers 1076, folding boards 1062 may be spaced closer together in both the longitudinal and lateral directions, and thereby the flat sheet material is fan folded into a ribbon-like structure including a plurality of fan folded sheets. In some implementations, folding boards 1062 can be oriented in a fanned-out configuration as shown. In practice, except for the center location, the weakened lines, panels, and fold lines of the material being fan-folded will often be askew relative to all of the respective theoretical locations shown. Although folding boards 1062 form the fold lines, the sheet of material will slide over folding boards 1062 and gather towards the center of the sheet (e.g., a middle folding board) and the actual fold lines will often not be set until the material is past the folding board area and is ready to enter nip rollers 1076. It will be appreciated that the orientation of all folding boards 1062, as a group, as well as folding boards relative to one another, can depend on many factors. Such factors can include, without limitation, the characteristics of material being folded, the liquid add-on amount to the material, the strength of the weakened line between adjacent panels,

operating speeds, necking of the material, desired folding pattern for the sheets, or distance between roller assembly 1050 and nip rollers 1076. For example, the tension of the sheet can be adjusted (e.g., a draw in the range of about 1% to about 10%, or about 3% to about 6% or about 4%) to enhance the folding process depending on one or more of the just-discussed factors.

[0102] Referring now to FIGS. 11A and 11B, perspective views of an example dispensing container 1140 for a stack of sheets (e.g., at least two sheets 1022) produced from a nonwoven material (e.g., coform nonwoven web 204) are shown, according to some implementations. It will be appreciated that dispensing container 1140 is only one example of a container or packing for a stack of sheets of a nonwoven material (e.g., a stack of wet wipes) and that other types of packaging are contemplated herein. As shown, a plurality of sheets 1022 can be formed into a stack that includes any suitable number of individual sheets depending upon the desired packaging and end-use. For example, the stack of sheets of nonwoven material – in this example, wet wipes – can be configured to include at least about five sheets and desirably from about 16 to about 320 individual sheets, and more desirably from about 32 to about 160 sheets. The size and shape of the stack of sheets 1022 is dependent upon the size and shape of the package/dispenser and vice versa. For example, the length of an assembled stack of wet wipes sheets can be about 190 mm, with a height of about 90 mm and a width of about 100 mm.

[0103] Each sheet is generally rectangular in shape and defines a pair of opposite side edges and a pair of opposite end edges which can be referred to as a leading end edge and a trailing end edge. Each sheet defines an unfolded width and an unfolded length. The sheets can have any suitable unfolded width and length. For example, sheets of wet wipes can have an unfolded length of from about 2.0 to about 80.0 centimeters or from about 10.0 to about 26.0 centimeters and an unfolded width of from about 2.0 to about 80.0 centimeters or from about 10.0 to about 45.0 centimeters. Generally, sheets 1022 can include sheets formed of any suitable nonwoven material, including a coform nonwoven material as described above. However, for the purposes of this disclosure, sheets 1022 are generally produced from a roll of nonwoven material such as first roll 210 or second roll 212, described above, which has been wound using the system and methods described herein. For wet wipes, each sheet may have a dry basis weight of from about 25 to about 120 grams per square meter (gsm) or from about 40 to about 90 gsm.

[0104] In some implementations – particularly, for wet wipes – sheets 1022 can contain a liquid which can be any solution that can be absorbed into the wipes, thus making them “wet wipes.” The wipes can be moistened at any time before the wipes are used by the consumer. They can be moistened sometime during the manufacturing process before or contemporaneous with the plurality of wipes being sealed in a dispenser or other packaging for next use by a product user. The liquid contained within the wet wipes can include any suitable components which provide the desired wiping properties. For example, the components can include water, emollients, surfactants, preservatives, chelating agents, pH buffers, fragrances or combinations thereof. The liquid can also contain lotions, ointments and/or medicaments.

[0105] The amount of liquid or solution contained within each wet wipe can vary depending upon the type of material being used to provide the wet wipe, the type of liquid being used, the type of container being used to store the stack of wet wipes, and the desired end use of the wet wipe. Generally, each wet wipe can contain from about 25 to about 600 weight percent or from about 200 to about 400 weight percent liquid based on the dry weight of the wipe, for improved wiping in certain situations. To determine the liquid add-on, first, the weight of a just-manufactured dry wipe is determined. Then, the amount of liquid by weight equal to the weight of the just-manufactured dry wipe, or an increased amount of liquid measured as a percent add-on based on the weight of the just-manufactured dry wipe, is added to the wipe to make it moistened, and then known as a “wet wipe” or “wet wipes”. In some implementations, the wet wipe is made from a coform material comprising from about 30 to about 40 weight percent polymeric microfibers based on the dry weight of the wipe, the amount of liquid contained within the wet wipe can be from about 250 to about 350 weight percent or about 330 weight percent based on the dry weight of the wet wipe. If the amount of liquid is less than the above-identified range, the wet wipes can be too dry and may not adequately perform depending on the intended use. If the amount of liquid is greater than the above-identified range, the wet wipes can be over-saturated and soggy and the liquid can pool in the bottom of the container, as well as contribute to problems with adhesive 1092 sticking to the surface of sheets 1022.

[0106] The plurality of sheets 1022 (e.g., wet wipes) can be arranged in a package or dispenser in any manner which provides convenient and reliable one-at-a-time dispensing, and for wet wipes which assists the wet wipes in not becoming overly dry. Generally, a storage and

dispensing package 1140 includes a non-rigid container 1142 having sides 1150 with a top-end portion 1152 and a bottom-end portion 1154, where the sides and top and bottom end portions define a cavity 1156 within the container 1140. Cavity 1156 includes a storage portion 1158 for the wipes. Top-end portion 1152 can include a resealable mechanism 1100. A non-rigid baffle structure 1110 has a width and is located in between resealable mechanism 1100 and storage portion 1158, with baffle structure 1110 positioned between opposing sides 1150 of the container spaced apart from each other. Baffle structure 1110 thereby defines a dispensing portion 1160 of cavity 1156 overlying storage portion 1158.

[0107] Generally, resealable mechanism 1100 can be any type of mechanism that allows package 1140 to be opened, closed, and reopened multiple times during the life of the package, e.g., a zipper with or without a stopper, resealable adhesive, a clip, or other structure that achieves the result desired here. In use, resealable mechanism 1100 is opened and then access to dispensing portion 1160 is gained. The user then passes his or her hand, etc., through orifice 1180 to grab the first wipe in the stack of wipes. If orifice 1180 is a frangible seal, this must be broken before the user can pass his or her hand through the orifice. Once the user grabs the wipe, it can then pass through orifice 1180 and enter the dispensing portion 1160 as the user pulls it up. If the user does not immediately need the wipe, it can be left in the orifice partially dispensed where it can be maintained in place by baffle structure 1110 until desired later. The partially dispensed wipe will just rest in place in orifice 1180, part in the dispensing portion and part in the storage portion, conveniently ready for later dispensing in the pop-up format. If the user does immediately desire to use the wipe, it can pass the complete wipe through the dispensing portion and out of the package. Alternatively, the following wipe may need to be fetched out of the storage portion similar to the first wipe at a later time when it is desired, commonly called reach-in dispensing, if the user pushed the following wipe back into the storage portion after pop-up dispensing of the leading wipe. In either case, after the desired number of wipes are taken, the resealable mechanism can be sealed closed, with or without a wipe partially dispensed in the dispensing portion, as discussed previously. At a later time when another wipe(s) is desired, the preceding steps can generally be followed again.

Stack Height Variability and Example Test Results

[0108] As discussed above, variability in the thickness of a nonwoven web can cause significant issues when converting to a finished or “end” product downstream. Variability in the thickness of a nonwoven web can be particularly pronounced when multiple sheets are stacked, which compounds these variations (e.g., in some implementations, each folded sheet in the stack contributes approximately two layers). For example, two stacks of 10 layers (e.g., 5 folded sheets) of a nonwoven web may be formed where the first stack is produced from a first section of a roll and the second stack is produced from a second section of the roll. In this example, the layers of nonwoven web in the first section of the roll may be 0.1 mm thinner (i.e., having a lesser thickness) than the layers in the second section of the roll. The 0.1 mm difference in thickness compounds to a 1 mm difference in height between the 10-layer stacks.

[0109] In practice, this example stack height variability can be seen when converting a nonwoven web into stacks of sheets, such as sheets 1022 (e.g., wipes), as described above. For example, when a roll of nonwoven web is converted into stacks of sheets for wet wipes, each stack—having the same number of layers—may vary in height with respect to other stacks produced from the same roll. Across a significantly large roll of material, these variations in stack height may be clearly visible, e.g., when the end product (e.g., a stack of wet wipes) is packaged and displayed. In other words, stacks produced from one section of a roll may be visibly taller (or shorter) than stacks produced from another section of the same roll.

[0110] To demonstrate the effects of the draw profile on stack height variability, multiple sample rolls of a nonwoven web were produced using (i) a standard constant draw technique and (ii) the variable winder draw profile described herein (e.g., as shown and described with respect to FIGS. 2-9). Then, the sample rolls were converted into stacks of folded sheets, herein referred to as “clips,” which were analyzed to determine how the variable draw technique described herein affects stack height variation in an example converted product (e.g., wipes). Generally, the “clip” referred to herein is a stack of eight folded sheets of a nonwoven web; however, it will be appreciated that a “clip” can include additional folded sheets or fewer folded sheets in various other implementations. For example, in the description of FIGS. 10A-11B, above, a clip refers to only two sheets. Thus, the present disclosure is not intended to be limiting. Additionally, one example system and technique for converting rolls of material into stacks of folded sheets is

described above; however, it will be appreciated that any suitable system and technique for producing stacks of folded sheets from a roll of nonwoven web may be used.

[0111] Referring now to FIG. 12, a graph illustrating and comparing the stack height variability results for the testing described above is shown, according to some implementations. In particular, the graph of FIG. 12 shows recorded heights for (i) about 2700 clips produced from a first sample roll of a nonwoven web that was wound at a constant draw, represented as constant draw datapoints 1202, and (ii) about 2700 clips produced from a second sample roll of a nonwoven web that was wound using the disclosed variable winder draw profile (e.g., shown in FIG. 6), represented as variable draw datapoints 1204. As shown in FIG. 12, constant draw datapoints 1202 show a much greater variability than variable draw datapoints 1204 (e.g., constant draw datapoints 1202 are shown to trend downward); thus, the height of clips produced from the “constant draw roll” (e.g., represented by constant draw datapoints 1202) tend to vary much more significantly than the height of clips produced from the “variable draw roll” (e.g., represented by variable draw datapoints 1204). In fact, the clip height data of FIG. 12 demonstrates that the disclosed system and methods for varying winder draw during winding results in a surprisingly smaller variation in clip height over the entire unwind of a roll.

[0112] Table 1 provides an analysis of the clip data shown in FIG. 12. As shown in Table 1, the standard deviation in clip height is reduced from 0.207 (for clips produced from a constant draw roll) to 0.137 (for clips produced from a variable draw roll). Table 1 also shows that the coefficient of variation is reduced from 0.022 (for clips produced from a constant draw roll) to 0.015 (for clips produced from a variable draw roll). In plain terms, clip heights were much more consistent among clips produced from the sample variable draw roll than from the sample constant draw roll.

Table 1. – Clip Height Comparison (in mm)

	Average Clip Height	StDev Clip Height	Coefficient of Variation of Clip Height
Constant Draw	9.284	0.207	0.022
Variable Draw	9.024	0.137	0.015

[0113] Further investigation – as illustrated in Table 2 – shows that the average clip height decays as the roll unwinds using a standard constant draw profile. Indeed, using a constant draw profile, the average clip height for clips formed from the first 10% of the roll (the outermost portion of the roll) was 9.429 mm, while the average clip height for clips formed from the final 10% of the roll (the innermost portion of the roll) was 8.937 mm. In other words, the average clip height for clips formed from the final 10% of the roll was 5.3% shorter than the average clip height for clips formed from the first 10% of the roll. This inconsistency would result in substantial variation in stack heights for clips produced from the same roll.

[0114] As further demonstrated in Table 2, the use of a variable draw profile solves this problem. Using the variable winder draw profile described herein, the average clip height for clips formed from the first 10% of the roll (the outermost portion of the roll) was 9.057 mm, while the average clip height for clips formed from the final 10% of the roll (the innermost portion of the roll) was 8.914 mm. In other words, the average clip height for clips formed from the final 10% of the roll was only 1.6% shorter than the average clip height for clips formed from the first 10% of the roll. This improved consistency would reduce substantial variations in stack heights for clips produced from the same roll.

Table 2. – Average Clip Height (mm) Throughout Roll

	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
Constant	9.429	9.400	9.367	9.374	9.343	9.337	9.302	9.220	9.138	8.937
Variable	9.057	9.037	9.038	9.018	9.037	9.039	9.032	9.038	9.031	8.914

[0115] It was also found the rate of change in clip height for stacks of sheets converted from a roll that is wound at a constant draw starts to increase at around 70% of the unwind roll. In other words, when about 30% of the roll remains to be unwound, the rate of variation in the clip height increases in magnitude (c.f., 9.429 mm @ 0-10%; 9.302 mm @ 60-70%; 8.937 mm @ 90-100%). By contrast, the rate of variation in the clip height for stacks of sheets converted from a roll that is wound using the disclosed variable draw technique remains relatively constant throughout the unwind roll (c.f., 9.057 mm @ 0-10%; 9.032 mm @ 60-70%; 8.914 mm @ 90-100%).

[0116] These results are further illustrated in FIG. 13 and Table 3, which show an increase in the rate of change of average clip height at around 70% of the unwind roll. In fact, even in the last 10% of the roll (e.g., the 10% of the roll closest to the core), the sample variable draw roll demonstrates a lower rate of change than the sample constant draw roll.

Table 3. – Rate of Change (mm/% Roll) in Clip Height Throughout Roll

	10:20%	20:30%	30:40%	40:50%	50:60%	60:70%	70:80%	80:90%	90:100%
Constant	-0.0029	-0.0034	0.0007	-0.0031	-0.0005	-0.0035	-0.0082	-0.0083	-0.0201
Variable	-0.0020	0.0002	-0.0020	0.0019	0.0002	-0.0007	0.0006	-0.0007	-0.0118

Configuration of Certain Implementations

[0117] The construction and arrangement of the systems and methods as shown in the various implementations are illustrative only. Although only a few implementations have been described in detail in this disclosure, many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes, and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.). For example, the position of elements may be reversed or otherwise varied, and the nature or number of discrete elements or positions may be altered or varied. Accordingly, all such modifications are intended to be included within the scope of the present disclosure. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative implementations. Other substitutions, modifications, changes, and omissions may be made in the design, operating conditions, and arrangement of the implementations without departing from the scope of the present disclosure.

[0118] The present disclosure contemplates methods, systems, and program products on any machine-readable media for accomplishing various operations. The implementations of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Implementations within the scope of the present disclosure include program products including machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine

with a processor. By way of , such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures, and which can be accessed by a general purpose or special purpose computer or other machine with a processor.

[0119] When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or a combination of hardwired or wireless) to a machine, the machine properly views the connection as a machine-readable medium. Thus, any such connection is properly termed a machine-readable medium. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general-purpose computer, special-purpose computer, or special-purpose processing machines to perform a certain function or group of functions.

[0120] Although the figures show a specific order of method steps, the order of the steps may differ from what is depicted. Also, two or more steps may be performed concurrently or with partial concurrence. Such variation will depend on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the disclosure. Likewise, software implementations could be accomplished with standard programming techniques with rule-based logic and other logic to accomplish the various connection steps, processing steps, comparison steps and decision steps.

[0121] It is to be understood that the methods and systems are not limited to specific synthetic methods, specific components, or to particular compositions. It is also to be understood that the terminology used herein is for the purpose of describing particular implementations only and is not intended to be limiting.

[0122] As used in the specification and the appended claims, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Ranges may be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another implementation includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another

implementation. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

[0123] “Optional” or “optionally” means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where said event or circumstance occurs and instances where it does not.

[0124] Throughout the description and claims of this specification, the word “comprise” and variations of the word, such as “comprising” and “comprises,” means “including but not limited to,” and is not intended to exclude, for example, other additives, components, integers or steps. “Exemplary” means “an example of” and is not intended to convey an indication of a preferred or ideal implementation. “Such as” is not used in a restrictive sense, but for explanatory purposes.

[0125] Disclosed are components that can be used to perform the disclosed methods and systems. These and other components are disclosed herein, and it is understood that when combinations, subsets, interactions, groups, etc. of these components are disclosed that while specific reference of each various individual and collective combinations and permutation of these may not be explicitly disclosed, each is specifically contemplated and described herein, for all methods and systems. This applies to all aspects of this application including, but not limited to, steps in disclosed methods. Thus, if there are a variety of additional steps that can be performed it is understood that each of these additional steps can be performed with any specific implementation or combination of implementations of the disclosed methods.

Example Implementations

Example 1: A method of manufacturing nonwoven material, the method comprising: feeding a nonwoven web across a winding drum and onto a core; operating the winding drum to wind the nonwoven web around the core to form a roll of the nonwoven web; and controlling a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first magnitude, and ii) subsequently decreased by a second magnitude, wherein the second magnitude is less than the first magnitude, wherein the periodic increasing and subsequent decreasing of the draw is repeated until the roll reaches a threshold diameter.

Example 2: The method of example 1, further comprising measuring a diameter of the roll using a sensor.

Example 3: The method of example 2, wherein controlling the winding drum as the nonwoven web is wound onto the core further comprises: operating at an initial draw until the diameter of the roll reaches an initial threshold, wherein the periodic increasing and subsequent decreasing of the draw is initiated after the diameter of the roll reaches the second threshold diameter.

Example 4: The method of example 2, wherein, for each periodic increase and decrease of the draw, the draw is maintained: i) at an increased value until a diameter of the roll increases by a first amount, and ii) at a decreased value until the diameter of the roll increases by a second amount.

Example 5: The method of example 4, wherein the first amount is greater than the second amount.

Example 6: The method of example 5, wherein the first amount is four inches and the second amount is two inches.

Example 7: The method of example 1, wherein a value of each of the first magnitude and the second magnitude remains constant for each periodic increase and decrease of the draw.

Example 8: The method of example 1, wherein a value of one or both of the first magnitude and the second magnitude is different for each periodic increase and decrease of the draw.

Example 9: The method of example 1, wherein the first amount corresponds to a 0.75% increase in the draw.

Example 10: The method of example 1, wherein the second amount corresponds to 0.72% decrease in the draw.

Example 11: The method of example 1, wherein a tension of the nonwoven web during winding varies based on the periodic increase and decrease of the draw.

Example 12: The method of example 1, wherein the periodic decreasing of the draw by the second magnitude causes a plurality of relief layers to be formed in the roll, wherein each of the plurality of relief layers is wound at a decreased tension with respect to a tension of preceding and subsequent layers of the nonwoven web.

Example 13: The method of example 1, wherein the nonwoven web is a coform nonwoven web.

Example 14: The method of example 1, further comprising converting the roll of the nonwoven web into a plurality of stacks of folded sheets, including at least two stacks of folded sheets produced from between a first 10% and a last 10% of the roll of the nonwoven web, wherein a coefficient of variation between the at least two stacks of sheets is less than 0.02.

Example 15: A controller for a machine comprising a winding drum that winds a nonwoven web onto a core to form a roll of the nonwoven web, the controller comprising: one or more processors; and memory having instructions stored thereon that, when executed by the one or more processors, cause the controller to: operate the winding drum to wind the nonwoven web around the core to form the roll; and control a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first magnitude, and ii) subsequently decreased by a second magnitude, wherein the second magnitude is less than the first magnitude, wherein the periodic increasing and subsequent decreasing of the draw is repeated until the roll reaches a threshold diameter.

Example 16: The controller of example 15, wherein the instructions further cause the controller to: continuously or periodically measure a diameter of the roll using a sensor.

Example 17: The controller of example 16, wherein the instructions further cause the controller to: operate the winding drum at an initial draw until the diameter of the roll reaches an initial threshold, wherein the periodic increasing and subsequent decreasing of the draw is initiated after the diameter of the roll reaches the second threshold diameter.

Example 18: The controller of example 16, wherein, for each periodic increase and decrease of the draw, the draw is maintained: i) at the increased value until a diameter of the roll increases by a first amount, and ii) at the decreased value until the diameter of the roll increases by a second amount.

Example 19: The controller of example 18, wherein the first amount is greater than the second amount.

Example 20: The controller of example 19, wherein the third amount is four inches and the fourth amount is two inches.

Example 21: The controller of example 15, wherein the first magnitude corresponds to a 0.75% increase in the draw and the second magnitude corresponds to 0.72% decrease in the draw.

Example 22: The controller of example 15, wherein a tension of the nonwoven web during winding varies based on the periodic increase and decrease of the draw.

Example 23: The controller of example 15, wherein a value of each of the first magnitude and the second magnitude remains constant for each periodic increase and decrease of the draw speed.

Example 24: The controller of example 15, wherein the periodic decreasing of the draw by the second magnitude causes a plurality of relief layers to be formed in the roll, wherein each of the plurality of relief layers is wound at a decreased tension with respect to a tension of preceding and subsequent layers of the nonwoven web.

Example 25: The controller of example 15, wherein a value of one or both of the first magnitude and the second magnitude is different for each periodic increase and decrease of the draw.

Example 26: The controller of example 15, wherein the nonwoven web is a coform nonwoven web.

Example 27: A system for producing a roll of nonwoven web, the system comprising: a winding drum for winding the nonwoven web onto a core to form the roll; and a controller that operates the winding drum to: control a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first amount, and ii) subsequently decreased by a second amount, wherein the second amount is less than the first amount such that the draw speed of the winding drum is higher after decreasing by the second amount than it was prior to increasing by the first amount for each periodic increase and decrease of the draw.

Example 28: The system of example 27, the controller further configured to measure a diameter of the roll using a sensor.

Example 29: The system of example 28, wherein controlling the winding drum as the nonwoven web is wound onto the core further comprises: operating the winding drum according to an initial draw until the diameter of the roll reaches an initial threshold, wherein the periodic

increasing and subsequent decreasing of the draw is initiated after the diameter of the roll reaches the second threshold diameter.

Example 30: The system of example 28, wherein, for each periodic increase and decrease of the draw, the draw is maintained: i) at an increased value until a diameter of the roll increases by a first amount, and ii) at a decreased value until the diameter of the roll increases by a second amount.

Example 31: The system of example 30, wherein the first amount is greater than the second amount.

Example 32: The system of example 31, wherein the first amount is four inches and the second amount is two inches.

Example 33: The system of example 27, wherein a value of each of the first magnitude and the second magnitude remains constant for each periodic increase and decrease of the draw.

Example 34: The system of example 27, wherein a value of one or both of the first magnitude and the second magnitude is different for each periodic increase and decrease of the draw.

Example 35: The system of example 27, wherein the first amount corresponds to a 0.75% increase in the draw.

Example 36: The system of example 27, wherein the second amount corresponds to 0.72% decrease in the draw.

Example 37: The system of example 27, wherein a tension of the nonwoven web during winding varies based on the periodic increase and decrease of the draw.

Example 38: The system of example 27, wherein the periodic decreasing of the draw by the second magnitude causes a plurality of relief layers to be formed in the roll, wherein each of the plurality of relief layers is wound at a decreased tension with respect to a tension of preceding and subsequent layers of the nonwoven web.

Example 39: The system of example 27, wherein the nonwoven web is a coform nonwoven web.

Example 40: The system of example 27, further comprising an apparatus for converting the roll of the nonwoven web into a plurality of stacks of folded sheets, including at least two stacks of

folded sheets produced from between a first 10% and a last 10% of the roll of the nonwoven web, wherein a coefficient of variation between the at least two stacks of sheets is less than 0.02.

Example 41: A controller for a machine that produces rolls of coform nonwoven web, the machine comprising a winding drum that winds the coform nonwoven web onto a core to form a roll, the controller comprising: one or more processors; and memory having instructions stored thereon that, when executed by the one or more processors, cause the controller to: operate the winding drum to wind the coform nonwoven web onto the core to form the roll; and control the winding drum as the coform nonwoven web is wound onto the core to form the roll to vary a draw on the nonwoven web according to a step waveform draw profile, wherein the step waveform draw profile comprises a series of step-ups that define a plurality of peaks in the draw and a corresponding series of step-downs that define a plurality of valleys in the draw, wherein each of the series of step-ups is associated with an increase in the draw from a corresponding one of the plurality of valleys and each of the series of step-downs is associated with a decrease in the draw from a corresponding one of the plurality of peaks, the series of step-ups including at least a first step-up from an initial draw that defines a first valley, wherein each of the series of step-ups is larger in amplitude than a corresponding one of the series of step-downs such that each of the plurality of peaks is associated with a higher draw than a previous one of the plurality of peaks and each of the plurality of valleys is associated with a higher draw than a previous one of the plurality of valleys.

Example 42: The controller of example 41, wherein the controller is further configured to measure a diameter of the roll using a sensor.

Example 43: The controller of example 42, wherein the controller is further configured to determine the draw from the step waveform draw profile based on the diameter of the roll.

Example 44: The controller of example 42, wherein the controller is configured to increase the draw according to the first step-up after determining that the roll is above a threshold diameter.

Example 45: The controller of example 44, wherein the controller is configured to maintain the draw at each of the plurality of peaks until the diameter of the roll increases by four inches over the diameter of the roll at a most recent one of the series of step-ups.

Example 46: The controller of example 44, wherein the controller is configured to maintain the draw at each of the plurality of valleys until the diameter of the roll increases by two inches over the diameter of the roll at a most recent one of the series of step-downs.

Example 47: The controller of example 41, wherein each of the series of step-ups is associated with a 0.75% increase in the draw.

Example 48: The controller of example 41, wherein each of the series of step-downs is associated with a 0.72% decrease in the draw.

Example 49: A system for producing a roll of coform nonwoven web, the system comprising: a winding drum for winding the coform nonwoven web onto a core to form the roll; and a controller that operates the winding drum wind the coform nonwoven web onto the core to form the roll, the controller configured to control the winding drum as the coform nonwoven web is wound onto the core to form the roll to vary a draw on the nonwoven web according to a step waveform draw profile, wherein the step waveform draw profile comprises a series of step-ups that define a plurality of peaks in the draw and a corresponding series of step-downs that define a plurality of valleys in the draw, wherein each of the series of step-ups is associated with an increase in the draw from a corresponding one of the plurality of valleys and each of the series of step-downs is associated with a decrease in the draw from a corresponding one of the plurality of peaks, the series of step-ups including at least a first step-up from an initial draw that defines a first valley, wherein each of the series of step-ups is larger in amplitude than a corresponding one of the series of step-downs such that each of the plurality of peaks is associated with a higher draw than a previous one of the plurality of peaks and each of the plurality of valleys is associated with a higher draw than a previous one of the plurality of valleys.

Example 50: The system of example 49, wherein the controller is further configured to measure a diameter of the roll using a sensor.

Example 51: The system of example 50, wherein the controller is further configured to determine the draw from the step waveform draw profile based on the diameter of the roll.

Example 52: The system of example 51, wherein the controller is configured to increase the draw according to the first step-up after determining that the roll is above a threshold diameter.

Example 53: The system of example 52, wherein the controller is configured to maintain the draw at each of the plurality of peaks until the diameter of the roll increases by four inches over the diameter of the roll at a most recent one of the series of step-ups.

Example 54: The system of example 52, wherein the controller is configured to maintain the draw at each of the plurality of valleys until the diameter of the roll increases by two inches over the diameter of the roll at a most recent one of the series of step-downs.

Example 55: The system of example 49, wherein each of the series of step-ups is associated with a 0.75% increase in the draw.

Example 56: The system of example 49, wherein each of the series of step-downs is associated with a 0.72% decrease in the draw.

Example 57: A method of producing a roll of coform nonwoven web, the method comprising: feeding the coform nonwoven web across a winding drum and onto a core; operating the winding drum to wind the coform nonwoven web onto the core to form the roll; and controlling the winding drum as the coform nonwoven web is wound onto the core to form the roll to vary a draw on the nonwoven web according to a step waveform draw profile, wherein the step waveform draw profile comprises a series of step-ups that define a plurality of peaks in the draw and a corresponding series of step-downs that define a plurality of valleys in the draw, wherein each of the series of step-ups is associated with an increase in the draw from a corresponding one of the plurality of valleys and each of the series of step-downs is associated with a decrease in the draw from a corresponding one of the plurality of peaks, the series of step-ups including at least a first step-up from an initial draw that defines a first valley, wherein each of the series of step-ups is larger in amplitude than a corresponding one of the series of step-downs such that each of the plurality of peaks is associated with a higher draw than a previous one of the plurality of peaks and each of the plurality of valleys is associated with a higher draw than a previous one of the plurality of valleys.

Example 58: The method of example 57, further comprising: measuring a diameter of the roll using a sensor; and determining the draw from the step waveform draw profile based on the diameter of the roll.

Example 59: The method of example 58, further comprising at least one of: maintaining the draw at each of the plurality of peaks until the diameter of the roll increases by four inches over the diameter of the roll at a most recent one of the series of step-ups; or maintaining the draw at each of the plurality of valleys until the diameter of the roll increases by two inches over the diameter of the roll at a most recent one of the series of step-downs.

Example 60: The method of example 59, wherein each of the series of step-ups is associated with a 0.75% increase in the draw, and wherein each of the series of step-downs is associated with a 0.72% decrease in the draw.

Example 61: A method of winding coform nonwoven web into a roll using a surface winder, the surface winder comprising a winding drum configured to wind the coform nonwoven web around a core to form the roll, the method comprising: operating the winding drum at an initial draw value until a diameter of the roll reaches a first threshold; increasing a draw value of the winding drum by a first amount to a first increased draw value; operating the winding drum at the first increased draw value until the diameter of the roll reaches a second threshold; decreasing the draw value by a second amount to a first decreased draw value, wherein the second amount is less than the first amount, and wherein the first decreased draw value is greater than the initial draw value; operating the winding drum at the first decreased draw value until the diameter of the roll reaches a third threshold; and increasing the draw value by a third amount to a second increased draw value, wherein the second increased draw value is greater than the first increased draw value.

Example 62: The method of example 61, further comprising: operating the winding drum at the second increased draw value until the diameter of the roll reaches a fourth threshold; and decreasing the draw value by a fourth amount to a second decreased draw value, wherein the second decreased draw value is greater than the first decreased draw value.

Example 63: The method of example 61, further comprising measuring the diameter of the roll using a sensor to determine when the diameter of the roll reaches each of the first, second, and third thresholds.

Example 64: The method of example 61, wherein the first threshold is 14 inches.

Example 65: The method of example 61, wherein the second threshold is 18 inches.

Example 66: The method of example 61, wherein the third threshold is 20 inches.

Example 67: The method of example 61, wherein the first increased draw value is 0.75% greater than the initial draw value.

Example 68: The method of example 61, wherein the first decreased draw value is 0.72% less than the first increased draw value.

Example 69: The method of example 61, wherein the second decreased draw value is 0.75% greater than the first decreased draw value.

Example 70: A controller for a machine that produces rolls of coform nonwoven web, the machine comprising a winding drum that winds the coform nonwoven web onto a core to form a roll, the controller comprising: one or more processors; and memory having instructions stored thereon that, when executed by the one or more processors, cause the controller to: operate the winding drum at an initial draw value until a diameter of the roll reaches a first threshold; increase a draw value of the winding drum by a first amount to a first increased draw value; operate the winding drum at the first increased draw value until the diameter of the roll reaches a second threshold; decrease the draw value by a second amount to a first decreased draw value, wherein the second amount is less than the first amount, and wherein the first decreased draw value is greater than the initial draw value; operate the winding drum at the first decreased draw value until the diameter of the roll reaches a third threshold; and increase the draw value by a third amount to a second increased draw value, wherein the second increased draw value is greater than the increased draw value.

Example 71: The controller of example 70, wherein the instructions further cause the controller to: operate the winding drum at the second increased draw value until the diameter of the roll reaches a fourth threshold; and decrease the draw value by a fourth amount to a second decreased draw value, wherein the second decreased draw value is greater than the first decreased draw value.

Example 72: The controller of example 70, wherein the instructions further cause the controller to: measure the diameter of the roll using a sensor to determine when the diameter of the roll reaches each of the first, second, and third thresholds.

Example 73: The controller of example 70, wherein the first threshold is 14 inches.

Example 74: The controller of example 70, wherein the second threshold is 18 inches.

Example 75: The controller of example 70, wherein the third threshold is 20 inches.

Example 76: The controller of example 70, wherein the first increased draw value is 0.75% greater than the initial draw value.

Example 77: The controller of example 70, wherein the first decreased draw value is 0.72% less than the first increased draw value.

Example 78: The controller of example 70, wherein the second decreased draw value is 0.75% greater than the first decreased draw value.

Example 79: A system for producing a roll of coform nonwoven web, the system comprising: a winding drum for winding the coform nonwoven web onto a core to form the roll; and a controller configured to: operate the winding drum at an initial draw value until a diameter of the roll reaches a first threshold; increase a draw value of the winding drum by a first amount to a first increased draw value; operate the winding drum at the first increased draw value until the diameter of the roll reaches a second threshold; decrease the draw value by a second amount to a first decreased draw value, wherein the second amount is less than the first amount, and wherein the first decreased draw value is greater than the initial draw value; operate the winding drum at the first decreased draw value until the diameter of the roll reaches a third threshold; and increase the draw value by a third amount to a second increased draw value, wherein the second increased draw value is greater than the increased draw value.

Example 80: The system of example 79, wherein the controller is further configured to: operate the winding drum at the second increased draw value until the diameter of the roll reaches a fourth threshold; and decrease the draw value by a fourth amount to a second decreased draw value, wherein the second decreased draw value is greater than the first decreased draw value.

Example 81: The system of example 79, wherein the controller is further configured to: measure the diameter of the roll using a sensor to determine when the diameter of the roll reaches each of the first, second, and third thresholds.

Example 82: The system of example 79, wherein the first threshold is 14 inches.

Example 83: The system of example 79, wherein the second threshold is 18 inches.

Example 84: The system of example 79, wherein the third threshold is 20 inches.

Example 85: The system of example 79, wherein the first increased draw value is 0.75% greater than the initial draw value.

Example 86: The system of example 79, wherein the first decreased draw value is 0.72% less than the first increased draw value.

Example 87: The system of example 79, wherein the second decreased draw value is 0.75% greater than the first decreased draw value.

Example 88: A plurality of dispensing containers for dispensing stacked sheets from a single roll of nonwoven material, the plurality of dispensing containers comprising: a first dispensing container having a first stack of nonwoven sheets disposed therein, the first stack of nonwoven sheets comprising sheets formed from an innermost portion of the single roll of nonwoven material; and a second dispensing container having a second stack of nonwoven sheets disposed therein, the second stack of nonwoven sheets comprising sheets formed from an outermost portion of the single roll of nonwoven material; wherein the first stack of nonwoven sheets and the second stack of nonwoven sheets include the same number of sheets, and wherein the first stack of nonwoven sheets has a clip height that is within 4% of a clip height of the second stack of nonwoven sheets.

Example 89: The plurality of dispensing containers of example 88, wherein the first stack of nonwoven sheets has a clip height that is within 3% of the clip height of the second stack of nonwoven sheets.

Example 90: The plurality of dispensing containers of example 88, wherein the first stack of nonwoven sheets has a clip height that is within 2% of the clip height of the second stack of nonwoven sheets.

Example 91: The plurality of dispensing containers of example 88, wherein the innermost portion of the single roll of nonwoven material is the innermost 10% of the roll by diameter.

Example 92: The plurality of dispensing containers of example 88, wherein outermost portion of the single roll of nonwoven material is the outermost 10% of the roll by diameter.

Example 93: The plurality of dispensing containers of example 88, wherein first dispensing container comprises a package having an opening for dispensing sheets from the first stack of nonwoven sheets.

Example 94: The plurality of dispensing containers of example 88, wherein the second dispensing container comprises a package having an opening for dispensing sheets from the second stack of nonwoven sheets.

The plurality of dispensing containers of example 88, wherein the sheets that form the first stack of nonwoven sheets and the sheets that form the second stack of nonwoven sheets are moistened with a liquid, and wherein the first dispensing container and the second dispensing container are configured to retain the liquid within the sheets that form the first stack of nonwoven sheets and the second stack of nonwoven sheets, respectively.

WHAT IS CLAIMED IS:

1. A method of manufacturing nonwoven material, the method comprising:
feeding a nonwoven web across a winding drum and onto a core;
operating the winding drum to wind the nonwoven web around the core to form a roll of the nonwoven web; and
controlling a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first magnitude, and ii) subsequently decrease by a second magnitude, wherein the second magnitude is less than the first magnitude, and wherein the periodic increasing and subsequent decreasing of the draw is repeated until the roll reaches a threshold diameter.
2. The method of claim 1, further comprising measuring a diameter of the roll using a sensor.
3. The method of claim 2, wherein varying the draw comprises:
operating at an initial draw until the diameter of the roll reaches an initial threshold, wherein the periodic increasing and subsequent decreasing of the draw is initiated after the diameter of the roll reaches the initial threshold.
4. The method of claim 2, wherein, for each periodic increase and decrease of the draw, the draw is maintained: i) at an increased value until a diameter of the roll increases by a first amount, and ii) at a decreased value until the diameter of the roll increases by a second amount.
5. The method of claim 4, wherein the first amount is greater than the second amount.
6. The method of claim 1, wherein a value of each of the first magnitude and the second magnitude remains constant for each periodic increase and decrease of the draw.
7. The method of claim 1, wherein a value of one or both of the first magnitude and the second magnitude is different for each periodic increase and decrease of the draw.
8. The method of claim 1, wherein a tension of the nonwoven web during winding varies based on the periodic increase and decrease of the draw.

9. The method of claim 8, wherein the periodic decreasing of the draw by the second magnitude causes a plurality of relief layers to be formed in the roll, wherein each of the plurality of relief layers is wound at a decreased tension with respect to a tension of preceding and subsequent layers of the nonwoven web.
10. The method of claim 1, wherein the nonwoven web is a coform nonwoven web.
11. The method of claim 1, further comprising:
converting the roll of the nonwoven web into a plurality of stacks of folded sheets,
including at least two stacks of folded sheets produced from between a first 10% and a last 10% of the roll of the nonwoven web, wherein a coefficient of variation in height between the at least two stacks of sheets is less than 0.02.
12. A controller for a machine comprising a winding drum that winds a nonwoven web onto a core to form a roll of the nonwoven web, the controller comprising:
one or more processors; and
memory having instructions stored thereon that, when executed by the one or more processors, cause the controller to:
operate the winding drum to wind the nonwoven web around the core to form the roll of the nonwoven web; and
control a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first magnitude, and ii) subsequently decreased by a second magnitude, wherein the second magnitude is less than the first magnitude, wherein the periodic increasing and subsequent decreasing of the draw is repeated until the roll reaches a threshold diameter.
13. The controller of claim 12, wherein the instructions further cause the controller to:
continuously or periodically measure a diameter of the roll using a sensor.
14. The controller of claim 13, wherein the instructions further cause the controller to:
operate the winding drum according to an initial draw until the diameter of the roll reaches an initial threshold, wherein the periodic increasing and subsequent decreasing of the draw is initiated after the diameter of the roll reaches the initial threshold.

15. The controller of claim 13, wherein, for each periodic increase and decrease of the draw, the draw is maintained: i) at an increased value until a diameter of the roll increases by a first amount, and ii) at a decreased value until the diameter of the roll increases by a second amount and wherein the first amount is greater than the second amount.
16. The controller of claim 12, wherein a value of each of the first magnitude and the second magnitude remains constant for each periodic increase and decrease of the draw.
17. The controller of claim 12, wherein a value of one or both of the first magnitude and the second magnitude is different for each periodic increase and decrease of the draw.
18. The controller of claim 12, wherein the periodic decreasing of the draw by the second magnitude causes a plurality of relief layers to be formed in the roll, wherein each of the plurality of relief layers is wound at a decreased tension with respect to a tension of preceding and subsequent layers of the nonwoven web.
19. A system for producing a roll of nonwoven web, the system comprising:
a winding drum for winding the nonwoven web onto a core to form the roll; and
a controller that operates the winding drum to wind the nonwoven web around the core to form the roll, wherein the controller is configured to:
control a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first amount, and ii) subsequently decreased by a second amount, wherein the second amount is less than the first amount such that the draw of the winding drum is higher after decreasing by the second amount than it was prior to increasing by the first amount for each periodic increase and decrease of the draw.
20. The system of claim 19, further comprising an apparatus for converting the roll of the nonwoven web into a plurality of stacks of folded sheets, including at least two stacks of folded sheets produced from between a first 10% and a last 10% of the roll of the nonwoven web, wherein a coefficient of variation in height between the at least two stacks of sheets is less than 0.02.

21. A plurality of dispensing containers for dispensing stacked sheets from a single roll of nonwoven material, the plurality of dispensing containers comprising:

a first dispensing container having a first stack of nonwoven sheets disposed therein, the first stack of nonwoven sheets comprising sheets formed from an innermost portion of the single roll of nonwoven material; and

a second dispensing container having a second stack of nonwoven sheets disposed therein, the second stack of nonwoven sheets comprising sheets formed from an outermost portion of the single roll of nonwoven material;

wherein the first stack of nonwoven sheets and the second stack of nonwoven sheets include the same number of sheets, and wherein the first stack of nonwoven sheets has a clip height that is within 4% of a clip height of the second stack of nonwoven sheets.

22. The plurality of dispensing containers of claim 21, wherein the first stack of nonwoven sheets has a clip height that is within 3% of the clip height of the second stack of nonwoven sheets.

23. The plurality of dispensing containers of claim 21, wherein the first stack of nonwoven sheets has a clip height that is within 2% of the clip height of the second stack of nonwoven sheets.

24. The plurality of dispensing containers of claim 21, wherein the innermost portion of the single roll of nonwoven material is an innermost 10% of the roll by diameter.

25. The plurality of dispensing containers of claim 21, wherein outermost portion of the single roll of nonwoven material is an outermost 10% of the roll by diameter.

26. The plurality of dispensing containers of claim 21, wherein first dispensing container comprises a package having an opening for dispensing sheets from the first stack of nonwoven sheets.

27. The plurality of dispensing containers of claim 21, wherein the second dispensing container comprises a package having an opening for dispensing sheets from the second stack of nonwoven sheets.

28. The plurality of dispensing containers of claim 21, wherein the sheets that form the first stack of nonwoven sheets and the sheets that form the second stack of nonwoven sheets are moistened with a liquid, and wherein the first dispensing container and the second dispensing container are configured to retain the liquid within the sheets that form the first stack of nonwoven sheets and the second stack of nonwoven sheets, respectively.

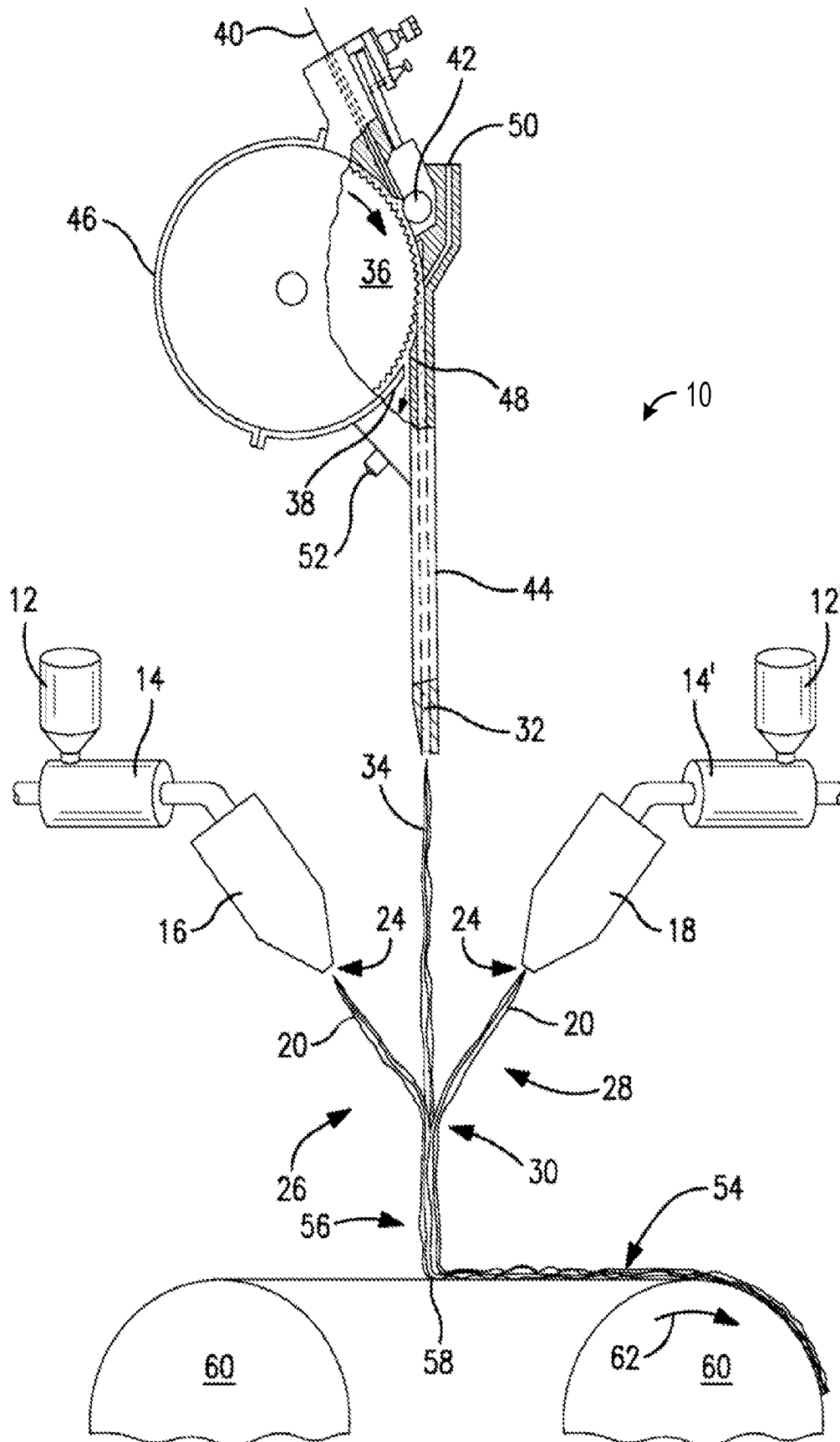


FIG. 1

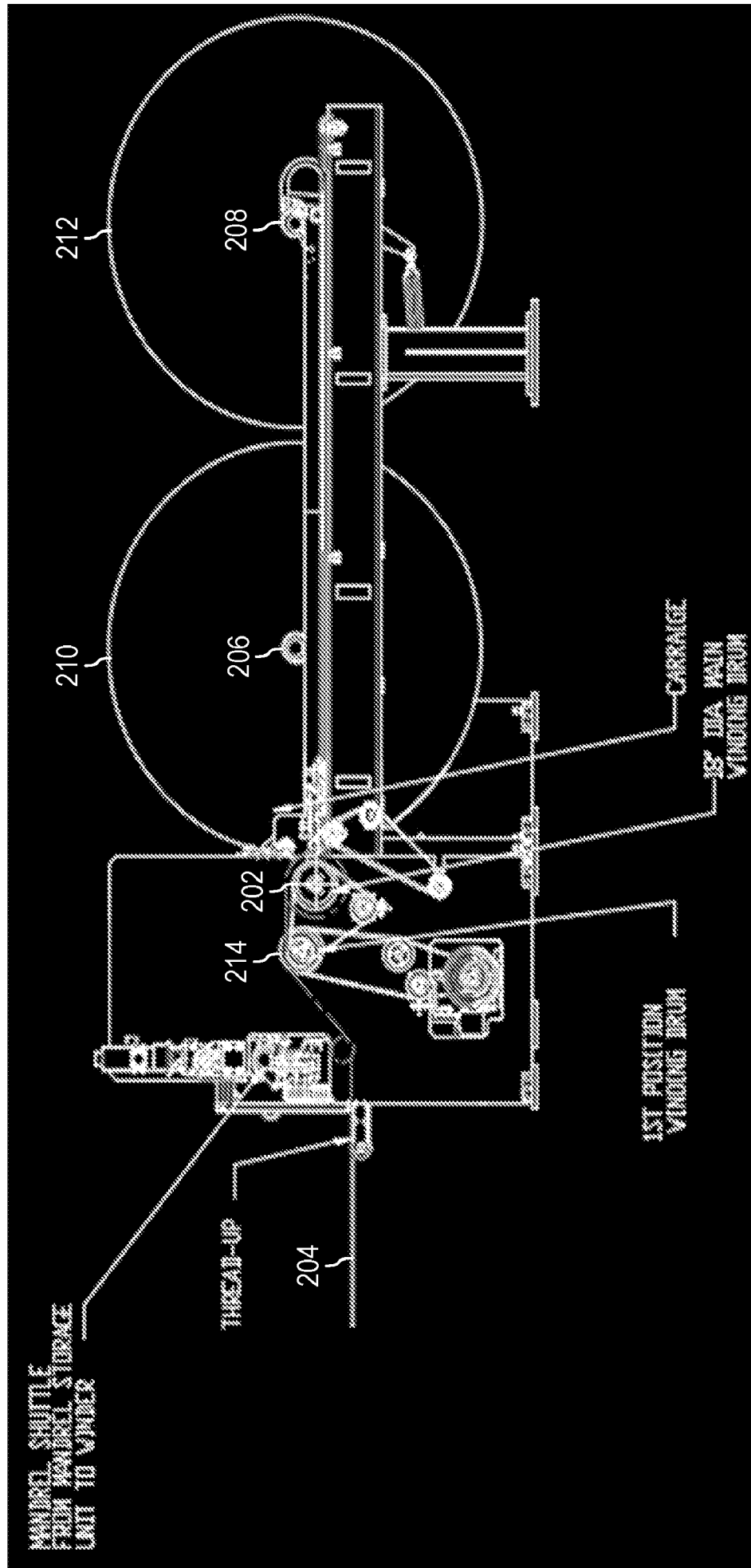


FIG. 2

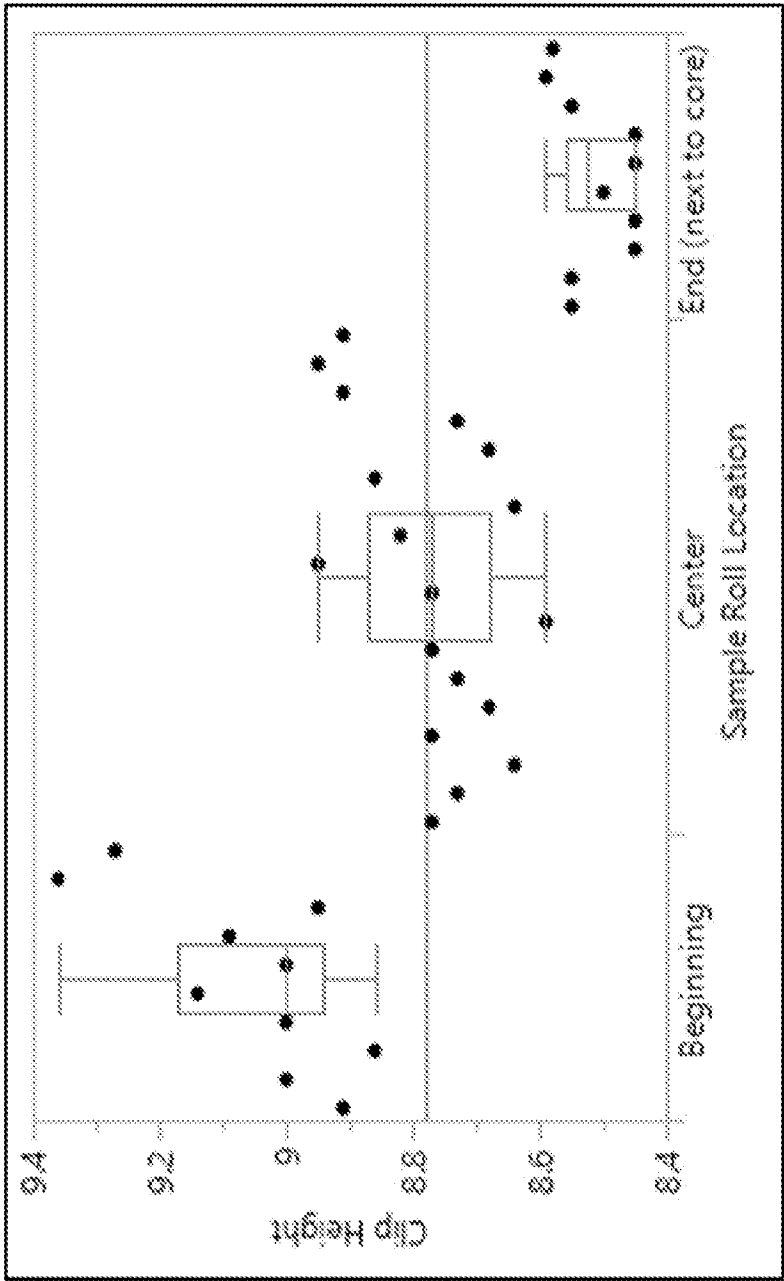


FIG. 3

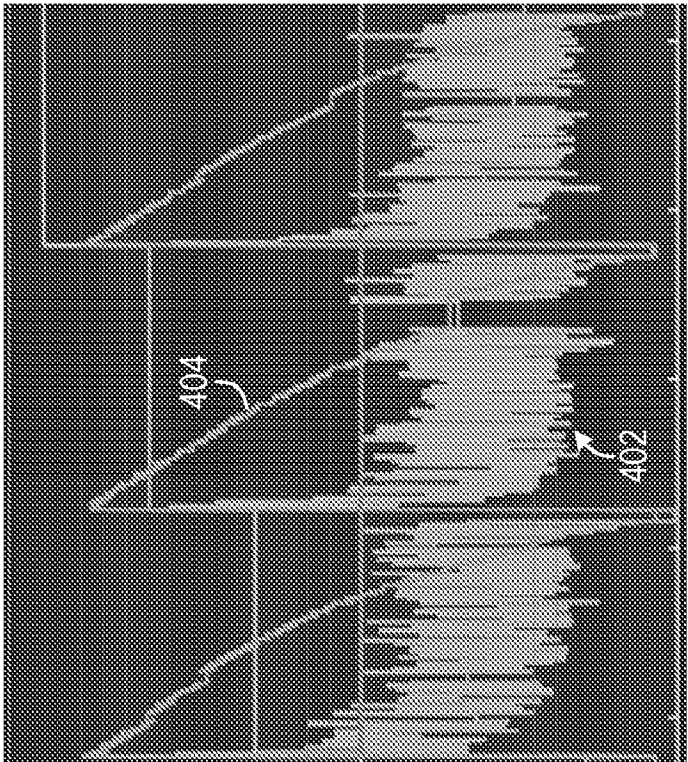


FIG. 4B

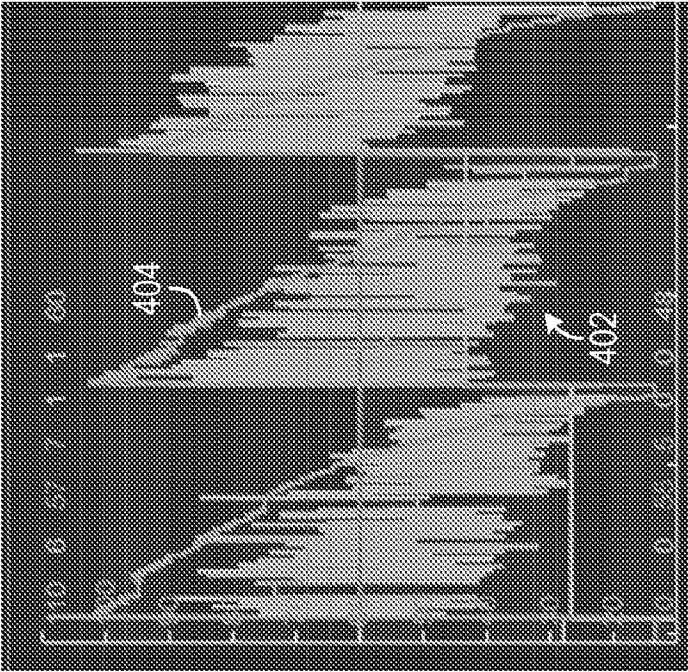


FIG. 4A

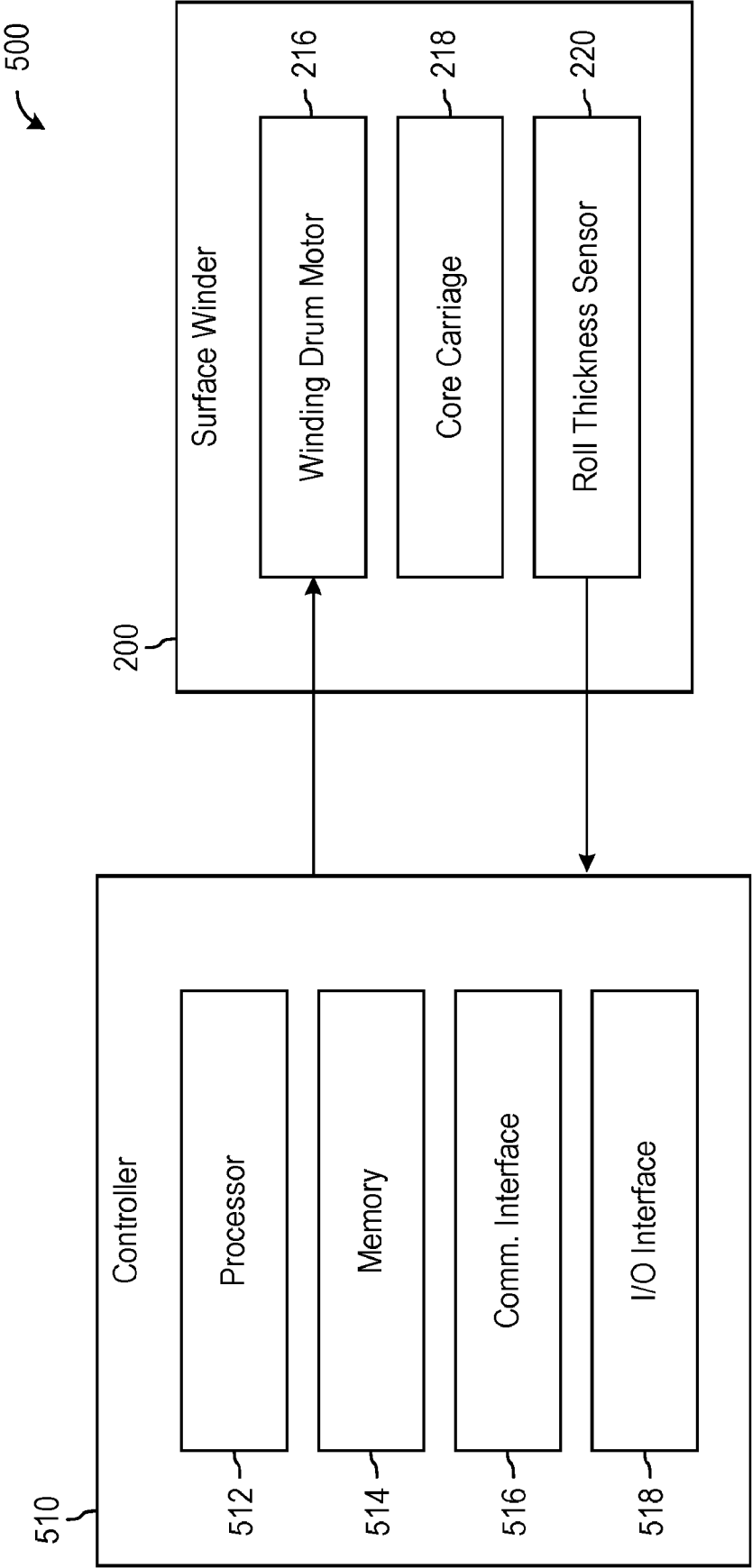


FIG. 5

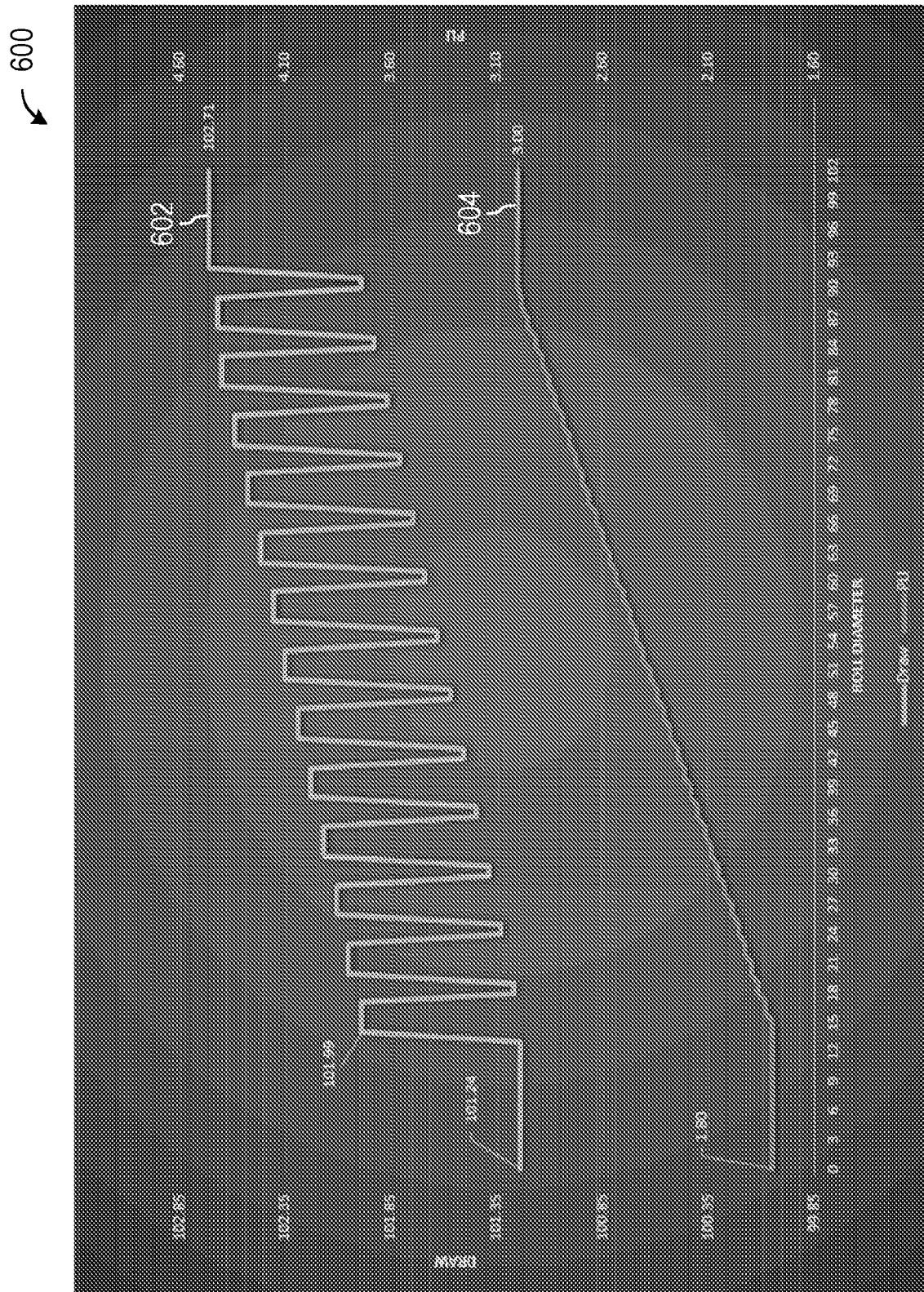


FIG. 6

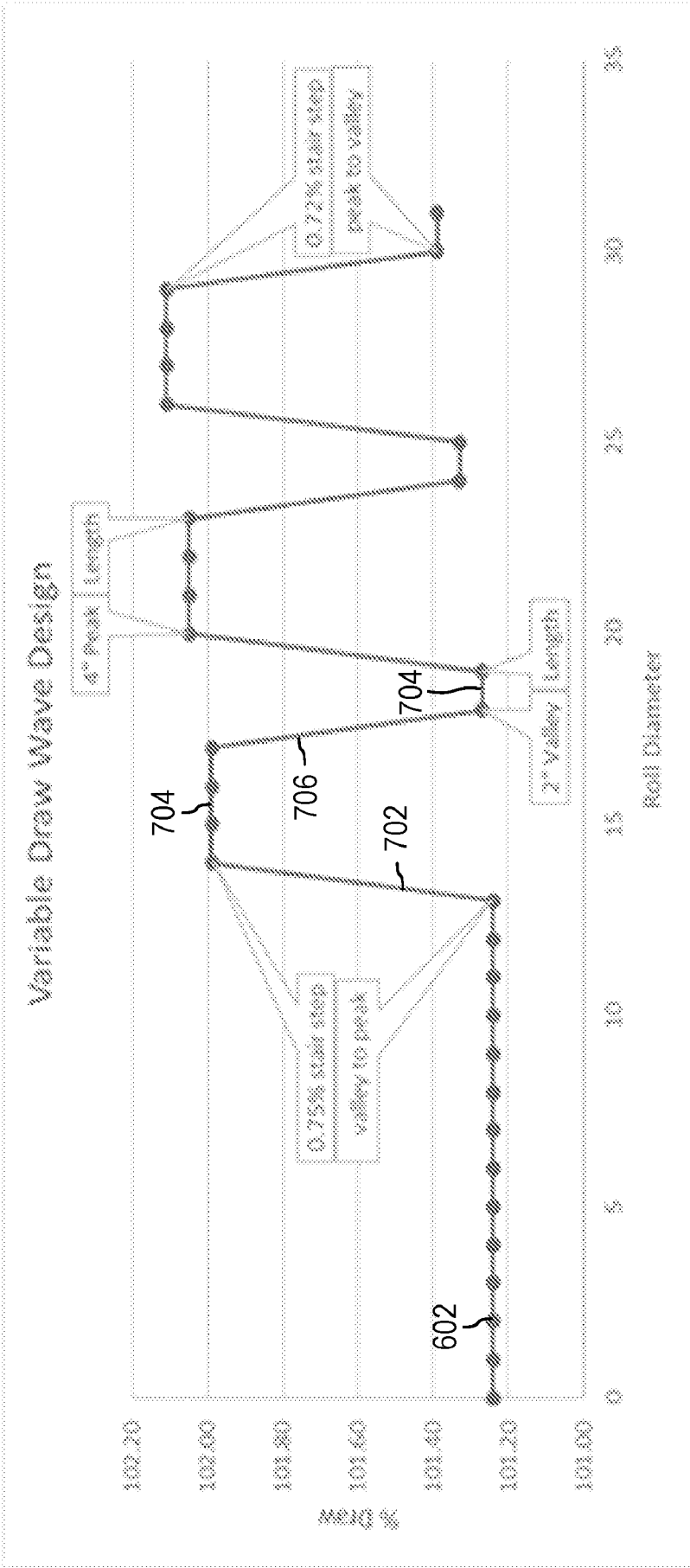
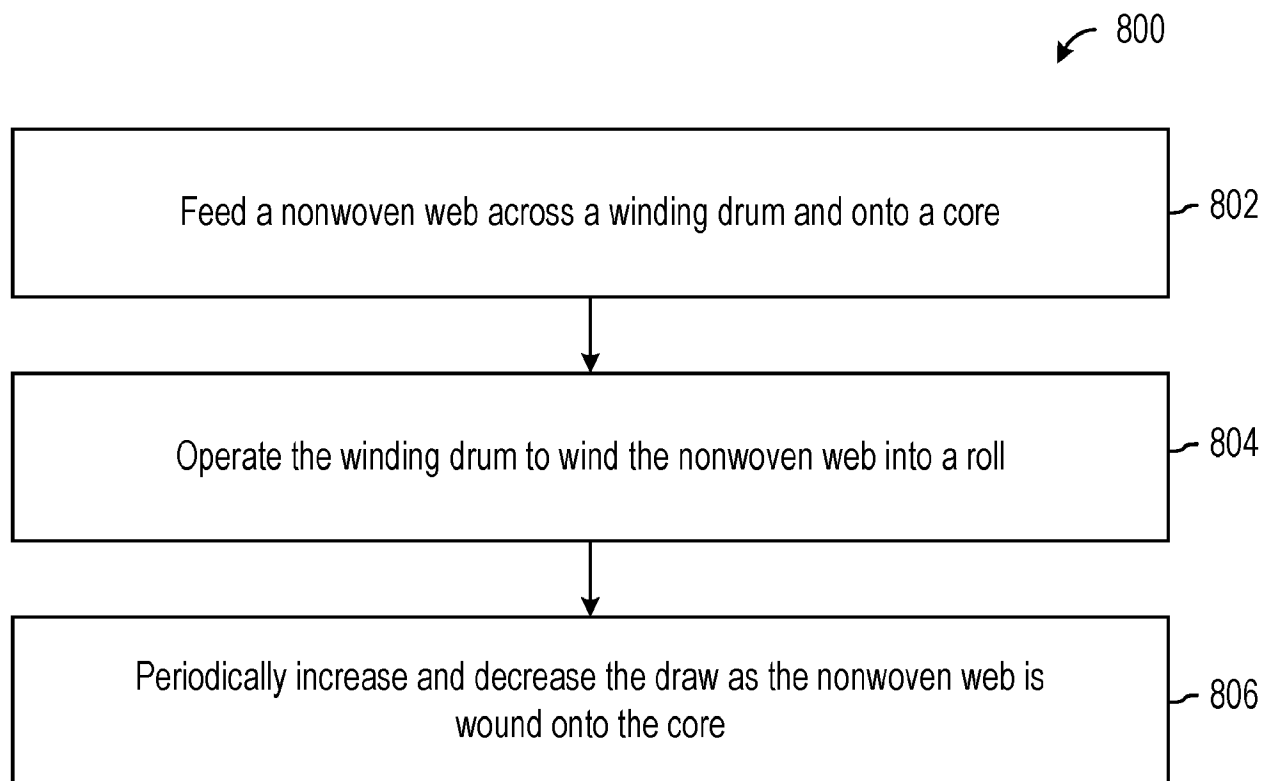
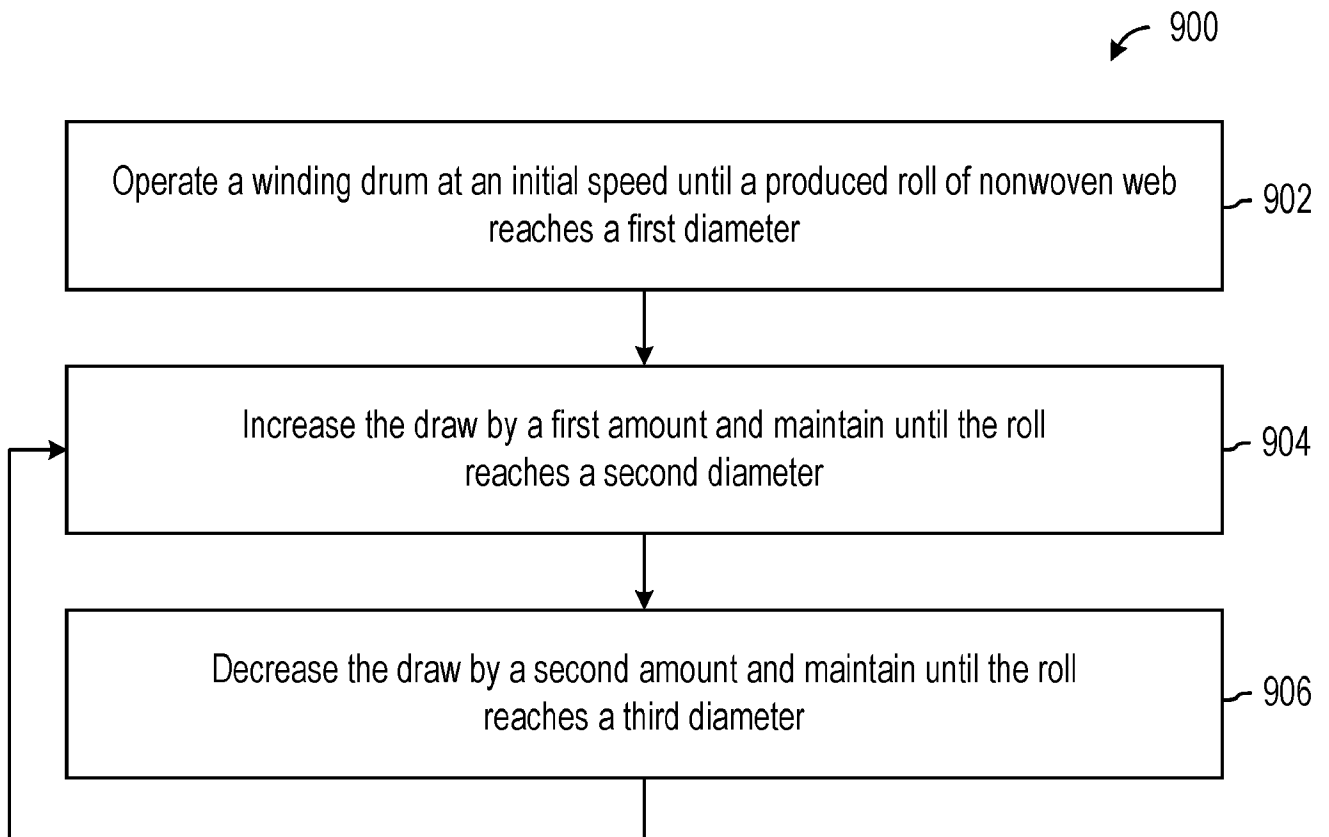


FIG. 7

**FIG. 8**

**FIG. 9**

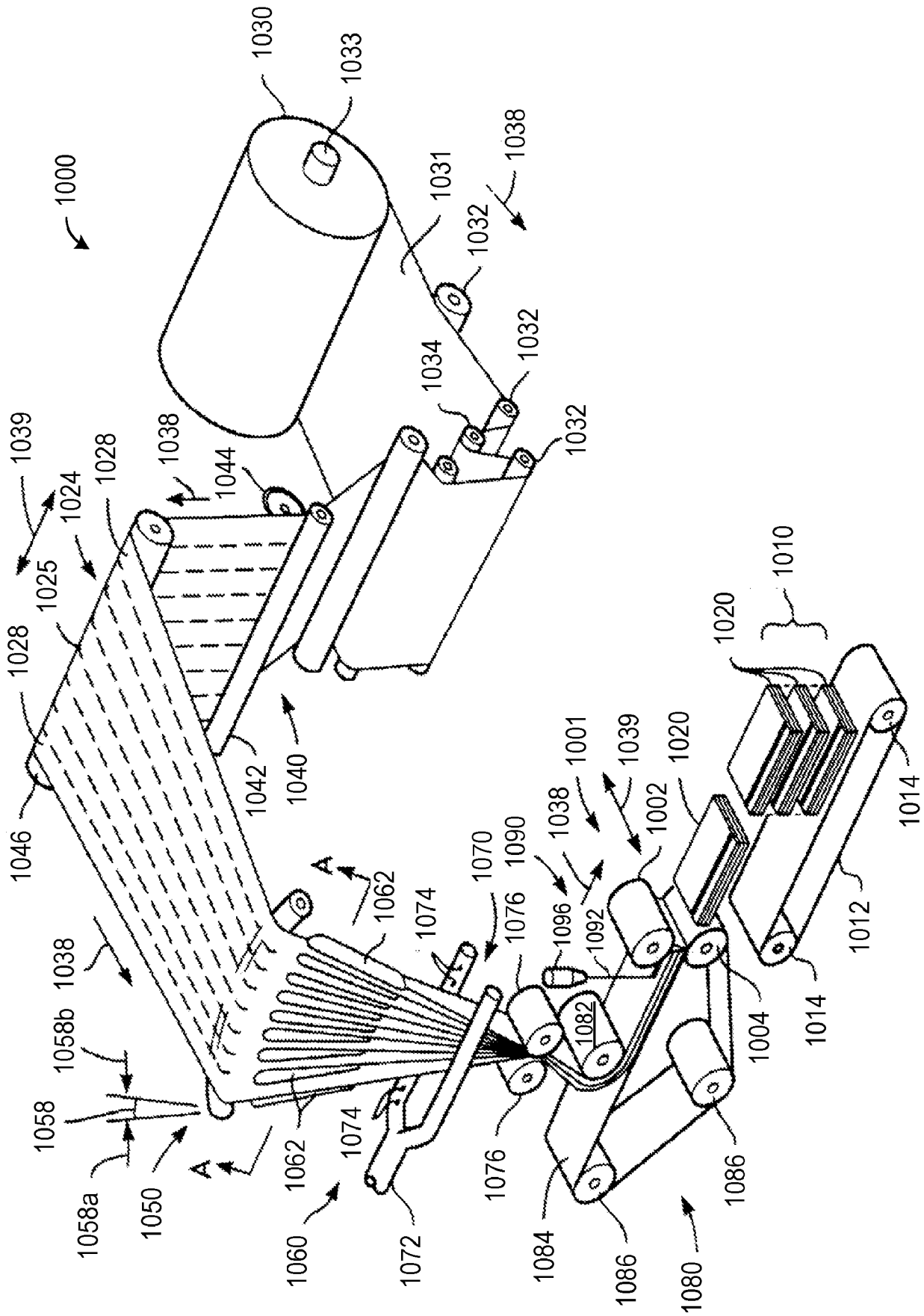


FIG. 10A



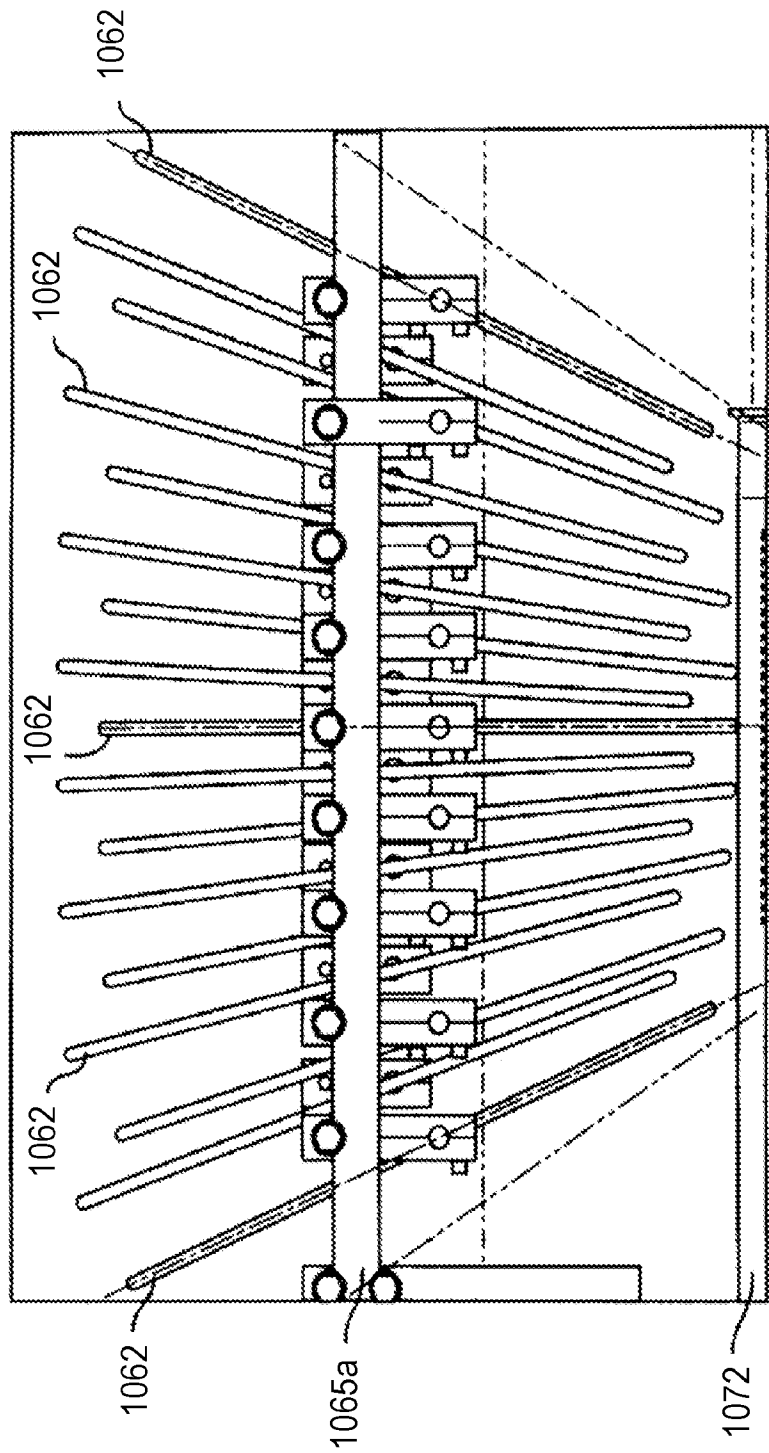


FIG. 10C

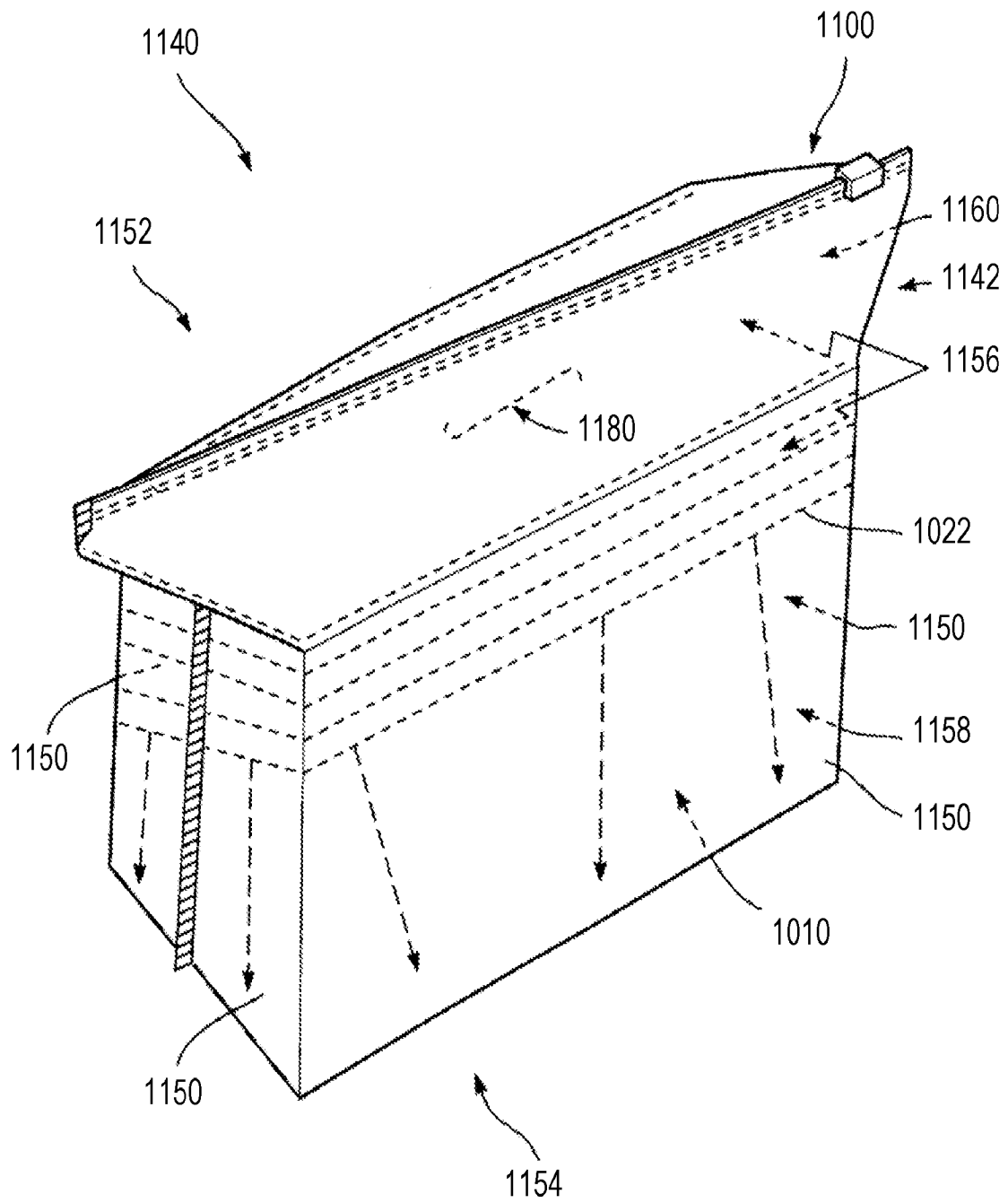


FIG. 11A

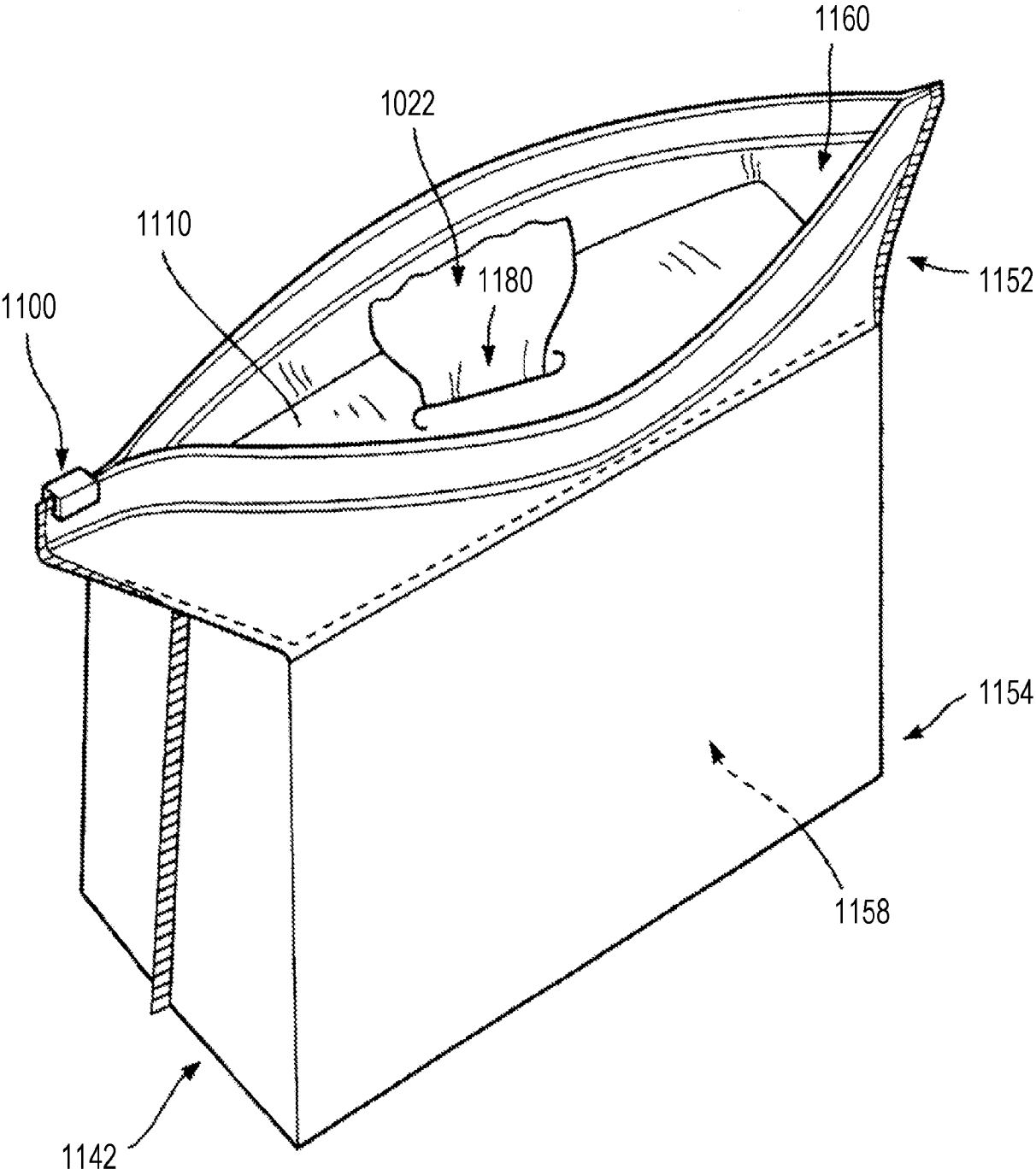


FIG. 11B

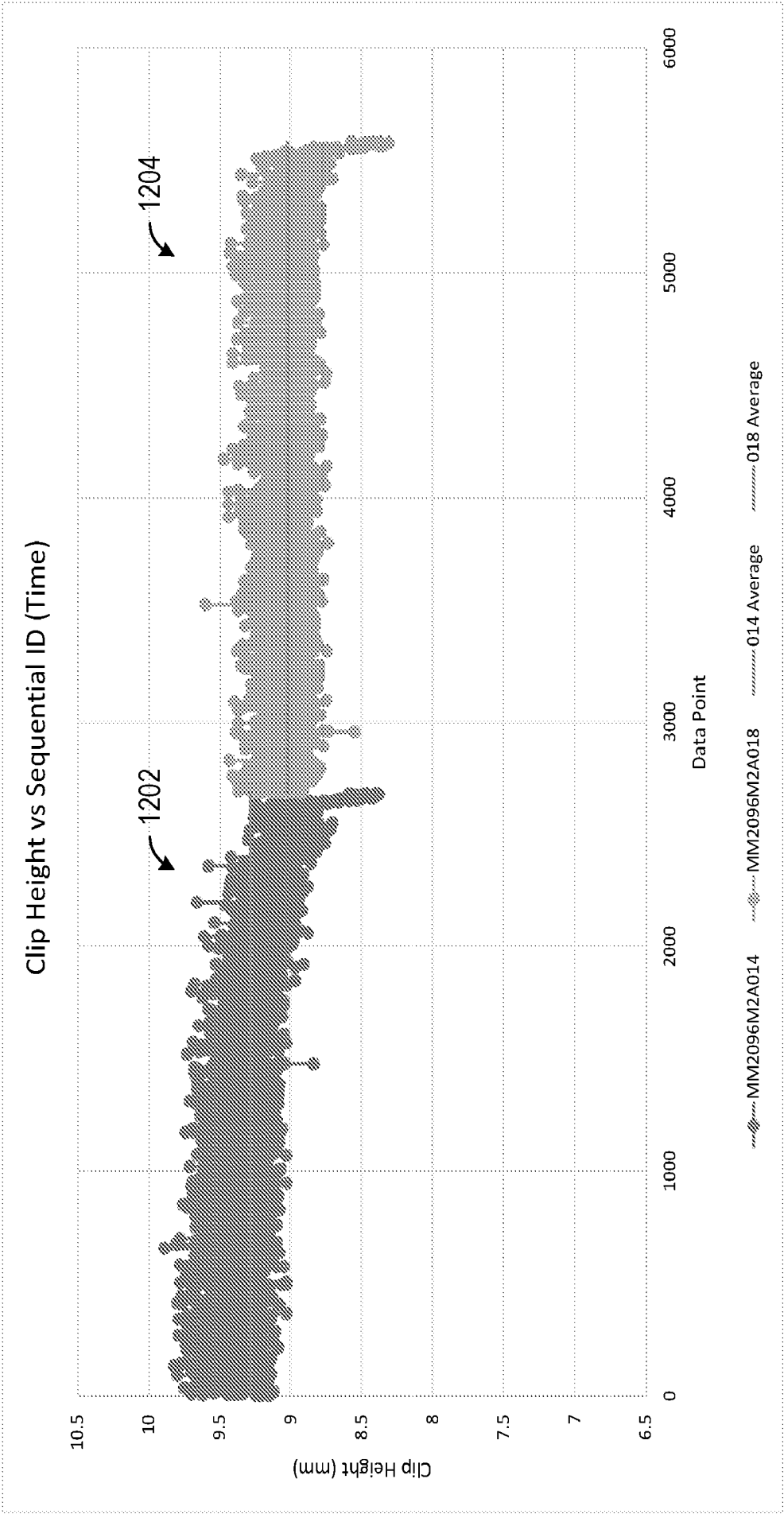


FIG. 12

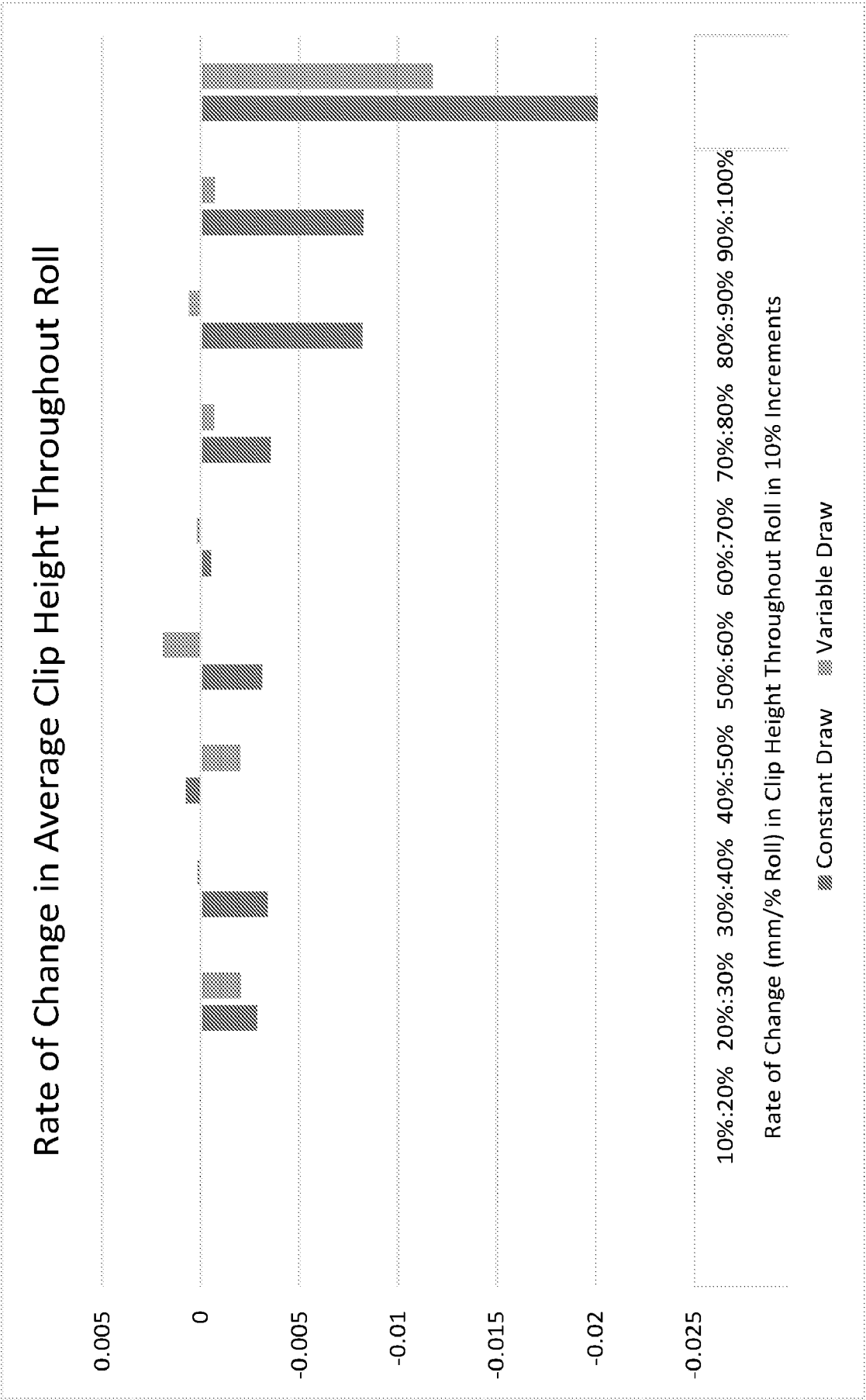


FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/025559

A. CLASSIFICATION OF SUBJECT MATTER

B65H 18/12 (2006.01) D04H 13/00 (2006.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B65H; D04H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

FAMPAT: nonwoven material, winding drum, core, roll, control, speed, periodically, first/second magnitude, increase, decrease, repeat, threshold diameter, and related terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2016/0280503 A1 (ERDEM GUELTEKIN, ET AL.) 29 September 2016 Paragraphs [0047]-[0049]; Figures 14, 15	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

*Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

14/02/2024

(day/month/year)

Date of mailing of the international search report

15/02/2024

(day/month/year)

Name and mailing address of the ISA/SG



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/025559

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:

because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:

because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:

because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please refer to Supplemental Box (Continuation of Box No. III).

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-20

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/025559

Supplemental Box (Continuation of Box No. III)

This International Searching Authority found multiple inventions in this international application, as follows:

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

Invention I: Claims 1-20 relate to a method/system of manufacturing nonwoven material, the method comprising: feeding a nonwoven web across a winding drum and onto a core; operating the winding drum to wind the nonwoven web around the core to form a roll of the nonwoven web; and controlling a speed of the winding drum by varying draw as the nonwoven web is wound onto the core, wherein the draw is periodically: i) increased by a first magnitude, and ii) subsequently decrease by a second magnitude, wherein the second magnitude is less than the first magnitude, and wherein the periodic increasing and subsequent decreasing of the draw is repeated until the roll reaches a threshold diameter.

Invention II: Claims 21-28 relate to a plurality of dispensing containers for dispensing stacked sheets from a single roll of nonwoven material, the plurality of dispensing containers comprising: a first dispensing container having a first stack of nonwoven sheets disposed therein, the first stack of nonwoven sheets comprising sheets formed from an innermost portion of the single roll of nonwoven material; and a second dispensing container having a second stack of nonwoven sheets disposed therein, the second stack of nonwoven sheets comprising sheets formed from an outermost portion of the single roll of nonwoven material; wherein the first stack of nonwoven sheets and the second stack of nonwoven sheets include the same number of sheets, and wherein the first stack of nonwoven sheets has a clip height that is within 4% of a clip height of the second stack of nonwoven sheets.

Please refer to **Box No. IV** of Written Opinion of The International Searching Authority (Form PCT/ISA/237) for detailed explanation.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2023/025559

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016/0280503 A1	29/09/2016	EP 3274284 A1 CN 107428486 A JP 2018510828 A WO 2016/153861 A1	31/01/2018 01/12/2017 19/04/2018 29/09/2016