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Headbox for Manufacturing a Substrate

Abstract

Apparatuses and processes for producing a substrate are described. A headbox is also provided. The headbox can include at least one flow section. The at least one flow section can include a constriction zone; a slice zone; an expansion zone; and a formation zone. A process for producing a web is also provided. The process can include depositing a slurry of fibers into a constriction zone. The slurry of fibers can then be flowed from the constriction zone through a slice zone and into an expansion zone. The slurry of fibers can then be flowed from the expansion zone into a formation zone. The slurry can be conveyed on a moving forming surface. Fluids may be drained from the slurry of fibers through the forming surface within the formation zone to form an embryonic web. The embryonic web may be dried.

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Background/Summary

FIELD OF THE INVENTION
[0001] The present invention is generally directed to apparatuses and methods for forming substrates. More specifically, the present disclosure relates to foam-forming methods and apparatuses for forming substrates.
BACKGROUND
[0002] Personal care products, such as diapers, diaper pants, training pants, adult incontinence products, and feminine care products, can include a variety of substrates. For example, a diaper can include an absorbent structure, nonwoven materials, and films. Similarly, facial tissues, wipes, and wipers can also include various substrates. Some of the substrates in these products can include natural and/or synthetic fibers. In some products, some substrates can also include different types of components to provide additional functionality to the substrate and/or the end product itself.
[0003] For example, one such component that may be desirable to add to a substrate includes a superabsorbent material (SAM). SAM can be configured in the form of a particle or a fiber and is commonly utilized in substrates for increased absorbent capacity. Absorbent systems of personal care absorbent products, such as a diaper, often include SAM. Processes exist for forming a substrate with SAM, including utilizing forming chambers to mix SAM particles or fibers with cellulosic fibers to form an absorbent core. These processes are generally completed in a dry environment, as SAM can be difficult to process when wet due to increase in volume from absorption of fluid and gelling, among other potential drawbacks. However, alternative substrate forming processes can employ fluids, such as liquids, to create substrates providing various other characteristics and efficiencies in manufacturing and performance of such substrates.
[0004] In order to improve various characteristics of tissue webs, webs have been formed according to a foam forming process. During a foam forming process, a slurry of fibers is created and spread onto a moving porous conveyor for producing an embryonic web. Foam formed webs can demonstrate improvements in bulk, stretch, caliper, and/or absorbency.
[0005] In addition to tissue webs, foam forming can be used to make all different types of webs and products. For example, relatively long fibers and synthetic fibers can be incorporated into webs using a foam forming process. Thus, foam forming processes can be more versatile than many wet laid processes.
[0006] When forming webs according to a foam forming process, however, problems have been experienced in controlling the fiber orientation in the resulting web. During production of the web, for instance, the foam suspends the fibers and conveys the fibers downstream at a flow rate that demonstrates plug flow characteristics and/or a low yield stress. Consequently, many foam forming processes produce webs in which the fibers are primarily oriented in the machine direction of the webmaking process, especially when the foam formed webs are formed on an inclined surface.
[0007] Thus, a need currently exists for a system and process of producing foam formed webs in which there is control over the fiber orientation. In particular, a need exists for a process and system that can produce foam formed webs where the fiber orientation is more random and results

in fibers being oriented in the machine direction and in the cross-machine direction. Producing webs with a more uniform fiber orientation distribution can provide various benefits and advantages. For instance, the webs can demonstrate a greater uniformity of physical properties between the machine direction of the web and the cross direction of the web. There also exists a need to develop improved headboxes for forming substrates.

SUMMARY

[0008] In one embodiment, a headbox is provided. The headbox can include a machine direction, a cross direction, and a height direction. The headbox can further include at least one flow section. The at least one flow section can include a bottom surface and a top surface. The top surface can be opposite from the bottom surface in the height direction. The at least one flow section can include a constriction zone; a slice zone; an expansion zone; and a formation zone. The constriction zone can have an initial height (t.sub.i) and the height can constrict along the machine direction to a slice height (t.sub.s). The slice zone can be in fluid communication with a downstream end of the constriction zone and can have a slice length (l.sub.s) in the machine direction and a height equal to the slice height (t.sub.s) over the slice length (l.sub.s). The expansion zone can be in fluid communication with a downstream end of the slice zone and can have a beginning height equal to the slice height (t.sub.s) and the height can expand along the machine direction to an expansion height (t.sub.1). The formation zone can be in fluid communication with a downstream end of the expansion zone and can have a beginning height equal to the expansion height (t.sub.1) and the height can constrict along the machine direction to a formation height (t.sub.2).

[0009] In another embodiment, a process for producing a web is provided. The process can include depositing a slurry of fibers and optionally at least one other solid component (e.g., superabsorbent particles) into a constriction zone. The slurry of fibers can then be flowed from the constriction zone through a slice zone and into an expansion zone. The slurry can have a fluid flow rate and the slice zone can have a height (t.sub.s) and length (l.sub.s) such that the slurry of fibers can undergo turbulent flow within the expansion zone. The slurry of fibers can then be flowed from the expansion zone into a formation zone. The slurry can be conveyed on a moving forming surface. Fluids can be drained from the slurry of fibers through the forming surface within the formation zone to form an embryonic web. The embryonic web may be dried.

[0010] Other features and aspects of the present disclosure are discussed in greater detail below.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A full and enabling disclosure of the present disclosure is set forth more particularly in the remainder of the specification, including reference to the accompanying figures, in which:

[0012] FIG. **1** is a process schematic of an exemplary method for introducing a component into a fluid supply and forming a substrate including a component according to one embodiment of the present disclosure;

[0013] FIG. **2** is a detailed schematic of the component feed system, two mixing junctions, and two fluid supplies upstream of the headbox as depicted from the process schematic in FIG. **1**;

[0014] FIG. **3** is a cross-section of the first mixing junction and outlet conduit of the component feed system of FIG. **2**;

[0015] FIG. **4**A is a process schematic of an alternative exemplary method for introducing a component into a fluid supply and forming a substrate including a component according to another embodiment of the present disclosure;

[0016] FIG. **4**B is a process schematic of another alternative exemplary method for introducing a component into a fluid supply and forming a substrate including a component according to another embodiment of the present disclosure;

[0017] FIG. **4**C is a process schematic of another alternative exemplary method for introducing a component into a fluid supply and forming a substrate including a component according to another embodiment of the present disclosure;
[0018] FIG. **5** is a side, cross-section view of an exemplary headbox;
[0019] FIG. **6** is a side, cross-section view of an exemplary headbox with a top layer flow channel.
[0020] Repeat use of reference characters in the present specification and drawings is intended to represent the same or analogous features or elements of the disclosure.

DETAILED DESCRIPTION

[0021] It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only and is not intended as limiting the broader aspects of the present disclosure.
[0022] The present disclosure is directed to methods and apparatuses that can produce a substrate including a component. While the present disclosure provides examples of substrates manufactured through foam-forming, it is contemplated that the methods and apparatuses described herein may be utilized to benefit wet-laid and/or air-laid manufacturing processes.
[0023] Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment or figure can be used on another embodiment or figure to yield yet another embodiment. It is intended that the present disclosure include such modifications and variations.
[0024] When introducing elements of the present disclosure or the preferred embodiment(s) thereof, the articles “a”, “an”, “the” and “said” are intended to mean that there are one or more of the elements. The terms “comprising”, “including” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. As used herein, the terminology of “first,” “second,” “third”, etc. does not designate a specified order, but is used as a means to differentiate between different occurrences when referring to various features in the present disclosure. Many modifications and variations of the present disclosure can be made without departing from the spirit and scope thereof. Therefore, the exemplary embodiments described herein should not be used to limit the scope of the invention.

Definitions

[0025] As used herein, the term “foam formed product” means a product formed from a suspension including a mixture of a solid, a liquid, and dispersed gas bubbles.
[0026] As used herein, the term “foam forming process” means a process for manufacturing a product involving a suspension including a mixture of a solid, a liquid, and dispersed gas bubbles.
[0027] As used herein, the term “foaming fluid” means any one or more known fluids compatible with the other components in the foam forming process. Suitable foaming fluids include, but are not limited to, water.
[0028] As used herein, the term “foam half life” means the time elapsed until the half of the initial frothed foam mass reverts to liquid water.
[0029] As used herein, the term “layer” refers to a structure that provides an area of a substrate in a height direction of the substrate that is comprised of similar components and structure.
[0030] As used herein, the term “nonwoven web” means a web having a structure of individual fibers or threads which are interlaid, but not in an identifiable manner as in a knitted web.
[0031] As used herein, unless expressly indicated otherwise, when used in relation to material compositions the terms “percent”, “%”, “weight percent”, or “percent by weight” each refer to the quantity by weight of a component as a percentage of the total except as whether expressly noted otherwise.
[0032] The term “personal care absorbent article” refers herein to an article intended and/or adapted to be placed against or in proximity to the body (i.e., contiguous with the body) of the wearer to absorb and contain various liquid, solid, and semi-solid exudates discharged from the body. Examples include, but are not limited to, diapers, diaper pants, training pants, youth pants,

swim pants, feminine hygiene products, including, but not limited to, menstrual pads or pants, incontinence products, medical garments, surgical pads and bandages, and so forth.

[0033] The term “ply” refers to a discrete layer within a multi-layered product wherein individual plies may be arranged in juxtaposition to each other.

[0034] The term “plied” or “bonded” or “coupled” refers herein to the joining, adhering, connecting, attaching, or the like, of two elements. Two elements will be considered plied, bonded or coupled together when they are joined, adhered, connected, attached, or the like, directly to one another or indirectly to one another, such as when each is directly bonded to intermediate elements. The plying, bonding or coupling of one element to another can occur via continuous or intermittent bonds.

[0035] The term “superabsorbent material” as used herein refers to water-swellable, water-insoluble organic or inorganic materials including superabsorbent polymers and superabsorbent polymer compositions capable, under the most favorable conditions, of absorbing at least about 10 times their weight, or at least about 15 times their weight, or at least about 25 times their weight in an aqueous solution containing 0.9 weight percent sodium chloride.

[0036] The term “machine direction” as used herein refers to the direction of travel of the forming surface onto which fibers are deposited during formation of a nonwoven web.

[0037] The term “height direction” as used herein refers to the direction from the top surface to the bottom surface of the flow section and is perpendicular to the machine direction defined above.

[0038] The term “cross-machine direction” as used herein refers to the direction which is perpendicular to both the machine direction and the height direction defined above.

[0039] The term “initial height” or “t.sub.i” as used herein refers to the distance between the top surface and the bottom surface at the most upstream portion of the constriction zone.

[0040] The term “slice height” or “t.sub.s” as used herein refers to the distance between the top surface and the bottom surface over the length of the slice zone. The slice height is also the distance between the top surface and the bottom surface at the most downstream portion of the constriction zone. The slice height is also the distance between the top surface and the bottom surface at the most upstream portion of the expansion zone.

[0041] The term “slice length” or “l.sub.s” as used herein refers to the distance along the machine direction over which the slice height is maintained.

[0042] The term “expansion height” or “t.sub.1” as used herein refers to the distance between the top surface and the bottom surface at the most downstream portion of the expansion zone.

[0043] The term “formation height” or “t.sub.2” as used herein refers to the distance between the top surface and the bottom surface at the most downstream portion of the formation zone.

[0044] The term “pulp” as used herein refers to fibers from natural sources such as woody and non-woody plants. Woody plants include, for example, deciduous and coniferous trees. Non-woody plants include, for example, cotton, flax, esparto grass, milkweed, straw, jute, hemp, and bagasse. Pulp fibers can include hardwood fibers, softwood fibers, and mixtures thereof.

[0045] The term “average fiber length” as used herein refers to an average length of fibers, fiber bundles and/or fiber-like materials determined by measurement utilizing microscopic techniques. A sample of at least 20 randomly selected fibers is separated from a liquid suspension of fibers. The fibers are set up on a microscope slide prepared to suspend the fibers in water. A tinting dye is added to the suspended fibers to color cellulose-containing fibers so they may be distinguished or separated from synthetic fibers. The slide is placed under a Fisher Stereomaster II Microscope—S19642/S19643 Series. Measurements of 20 fibers in the sample are made at 20× linear magnification utilizing a 0-20 mils scale and an average length, minimum and maximum length, and a deviation or coefficient of variation are calculated. In some cases, the average fiber length will be calculated as a weighted average length of fibers (e.g., fibers, fiber bundles, fiber-like materials) determined by equipment such as, for example, a Kajaani fiber analyzer Model No. FS-200, available from Kajaani Oy Electronics, Kajaani, Finland. According to a standard test procedure, a sample is treated with a macerating liquid to ensure that no fiber bundles or shives are present. Each sample is disintegrated into hot water and diluted to an approximately 0.001% suspension. Individual test samples are drawn in approximately 50 to 100 ml portions from the dilute suspension when tested using the standard Kajaani fiber analysis test procedure. The weighted average fiber length may be an arithmetic average, a length weighted average or a weight weighted average and may be expressed by the following equation:

[00001] .Math. $\sum_{x_i=0}^{k} (x_i * n_i) / n$ [0046] where [0047] k=maximum fiber length [0048] x.sub.i=fiber length [0049] n.sub.i=number of fibers having length xi [0050] n=total number of fibers measured.

[0051] One characteristic of the average fiber length data measured by the Kajaani fiber analyzer is that it does not discriminate between different types of fibers. Thus, the average length represents an average based on lengths of all different types, if any, of fibers in the sample.

[0052] As used herein the term “staple fibers” means discontinuous fibers made from synthetic polymers such as polypropylene, polyester, post consumer recycle (PCR) fibers, polyester, nylon, and the like, and those not hydrophilic may be treated to be hydrophilic. Staple fibers may be cut fibers or the like. Staple fibers can have cross-sections that are round, bicomponent, multicomponent, shaped, hollow, or the like.

[0053] In general, the present disclosure is directed to a process and system for forming non-woven webs from a liquid or foam suspension of fibers and optionally at least one other solid component. The system and process of the present disclosure use a unique and specially designed headbox that not only produces webs with uniform but random fiber orientation, but also in a manner that facilitates uniform distribution of another solid component, such as superabsorbent particles, that may be contained in the fiber slurry. The headbox design of the present disclosure is particularly well suited for use in series with other similar headboxes to produce a unified nonwoven web with uniform characteristics.

[0054] In one embodiment, the headbox design of the present disclosure includes an initial constriction zone that can be arced shaped in the height or Z direction. The constriction zone terminates at a slice zone that forms a slot through which the slurry is fed. After the slice zone, the slurry enters an expansion zone that can have a gradually increasing height. The headbox is designed such that the velocity of the slurry increases through the slice zone and then empties into the expansion zone where turbulent mixing of the slurry occurs. In one aspect, the slice zone followed by the expansion zone can cause a hydraulic jump that randomly and reorients the fibers in the slurry while also uniformly combining the fibers with the other solid component.

[0055] The headbox can also expand in width in the cross machine direction as the slurry travels from the constriction zone to the expansion zone. For instance, in one embodiment, the headbox can gradually taper and increase in width over the entire length of the headbox or at least over the length of the expansion zone. Consequently, not only does fiber and solid component mixing occur as flow progresses through the headbox, but also the flow of the slurry spreads out and increases in width. As described above, multiple headboxes can be placed in series for forming a web over the entire width of a forming surface. The headbox design is particularly well suited for producing a web from a series of laterally spaced headboxes without any noticeable fiber non-uniformities occurring where slurry flows converge that are exiting different headboxes.

[0056] In one embodiment, the dimensions of the headbox can be adjustable. For instance, the top of the headbox can be moveable towards and away from the bottom of the headbox. Thus, the different dimensions of the headbox can be varied and controlled depending upon the particular application and based upon the characteristics of the slurry. The headbox design of the present disclosure maintains flow velocity of the slurry high against any stationary surfaces, thus preventing fiber agglomeration or agglomeration of the solid component contained in the slurry, such as superabsorbent particles. Overall, the headbox design produces flow disruptions that provide web fiber randomization while spreading flow of the slurry without engaging in coaxial flow that has produced problems in prior systems.

[0057] Referring to the figures, in one embodiment, the present disclosure relates to a method and apparatus **10** that can form a substrate **12**. FIG. **1** provides a schematic of an exemplary apparatus **10** that can be used as part of a foam forming process to manufacture a substrate **12** that is a foam formed product. The apparatus **10** can include a first tank **14** configured for holding a first fluid supply **16**. In some embodiments, the first fluid supply **16** can be a foam. The first fluid supply **16** can include a fluid provided by a supply of fluid **18**. In some embodiments, the first fluid supply **16** can include a plurality of fibers provided by a supply of fibers **20**, however, in other embodiments, the first fluid supply **16** can be free from a plurality of fibers. The first fluid supply **16** can also include a surfactant provided by a supply of surfactant **22**. In some embodiments, the first tank **14** can include a mixer **24**, as will be discussed in more detail below. The mixer **24** can mix (e.g., agitate) the first fluid supply **16** to mix the fluid, fibers (if present), and surfactant with air, or some other gas, to create a foam. The mixer **24** can also mix the foam with fibers (if present) to create a foam suspension of fibers in which the foam holds and separates the fibers to facilitate a distribution of the fibers within the foam (e.g., as an artifact of the mixing process in the first tank **14**). Uniform fiber distribution can promote desirable substrate **12** including, for example, strength and the visual appearance of quality.

[0058] The apparatus **10** can also include a second tank **26** configured for holding a second fluid supply **28**. In some embodiments, the second fluid supply **28** can be a foam. The second fluid supply **28** can include a fluid provided by a supply of fluid **30** and a surfactant provided by a supply of surfactant **32**. In some embodiments, the second fluid supply **28** can include a plurality of fibers in addition to or as an alternative to the fibers being present in the first fluid supply **16**. In some embodiments, the second tank **26** can include a mixer **34**. The mixer **34** can mix the second fluid supply **28** to mix the fluid and surfactant with air, or some other gas, to create a foam.

[0059] For either or both the first tank **14** and the second tank **26**, the first fluid supply **16** or the second fluid supply **28** can be acted upon to form a foam. In some embodiments, the foaming fluid and other components are acted upon so as to form a porous foam having an air content greater than about 50% by volume and desirably an air content greater than about 60% by volume. In certain aspects, the highly-expanded foam is formed having an air content of between about 60% and about 95% and in further aspects between about 65% and about 85%. In certain embodiments, the foam may be acted upon to introduce air bubbles such that the ratio of expansion (volume of air to other components in the expanded stable foam) is greater than 1:1 and in certain embodiments the ratio of air:other components can be between about 1.1:1 and about 20:1 or between about 1.2:1 and about 15:1 or between about 1.5:1 and about 10:1 or even between about 2:1 and about 5:1.

[0060] The foam can be generated by one or more means known in the art. Examples of suitable methods include, without limitation, aggressive mechanical agitation such as by mixers **24**, **34**, injection of compressed air, and so forth. Mixing the components through the use of a high-shear, high-speed mixer is particularly well suited for use in the formation of the desired highly-porous foams. Various high-shear mixers are known in the art and believed suitable for use with the present disclosure. High-shear mixers typically employ a tank holding the foam precursor and/or one or more pipes through which the foam precursor is directed. The high-shear mixers may use a series of screens and/or rotors to work the precursor and cause aggressive mixing of the components and air. In a particular embodiment, the first tank **14** and/or the second tank **26** is provided having therein one or more rotors or impellors and associated stators. The rotors or impellors are rotated at high speeds in order to cause flow and shear. Air may, for example, be introduced into the tank at various positions or simply drawn in by the action of the mixers **24**, **34**. While the specific mixer design may influence the speeds necessary to achieve the desired mixing and shear, in certain embodiments suitable rotor speeds may be greater than about 500 rpm and, for example, be between about 1000 rpm and about 6000 rpm or between about 2000 rpm and about 4000 rpm. In certain embodiments, with respect to rotor based high-shear mixers, the mixer(s) **24**,

34 may be run with the foam until the disappearance of the vortex in the foam or a sufficient volume increase is achieved.

[0061] In addition, it is noted the foaming process can be accomplished in a single foam generation step or in sequential foam generation steps for the first tank **14** and/or the second tank **26**. For example, in one embodiment, all of the components of the first fluid supply **16** in the first tank **14** (e.g., the supply of the fluid **18**, fibers **20**, and surfactant **22**) may be mixed together to form a slurry from which a foam is formed. Alternatively, one or more of the individual components may be added to the foaming fluid, an initial mixture formed (e.g. a dispersion or foam), after which the remaining components may be added to the initially foamed slurry and then all of the components acted upon to form the final foam. In this regard, the fluid **18** and surfactant **22** may be initially mixed and acted upon to form an initial foam prior to the addition of any solids. Fibers, if desired, may then be added to the water/surfactant foam and then further acted upon to form the final foam. As a further alternative, the fluid **18** and fibers **20**, such as a high density cellulose pulp sheet, may be aggressively mixed at a higher consistency to form an initial dispersion after which the foaming surfactant, additional water and other components, such as synthetic fibers, are added to form a second mixture which is then mixed and acted upon to form the foam.

[0062] The foam density of the foam forming the first fluid supply **16** in the first tank **14** and/or the foam forming the second fluid supply **28** in the second tank **26** can vary depending upon the particular application and various factors, such as the fiber stock used. In some implementations, for example, the foam density of the foam can be greater than about 100 g/L, such as greater than about 250 g/L, such as greater than about 300 g/L. The foam density is generally less than about 800 g/L, such as less than about 500 g/L, such as less than about 400 g/L, such as less than about 350 g/L. In some implementations, for example, a lower density foam is used having a foam density of generally less than about 350 g/L, such as less than about 340 g/L, such as less than about 330 g/L.

[0063] In some embodiments, the apparatus **10** can also include a first pump **36** and a second pump **38**. The first pump **36** can be in fluid communication with the first fluid supply **16** and can be configured for pumping the first fluid supply **16** to transfer the first fluid supply **16**. The second pump **38** can be in fluid communication with the second fluid supply **28** and can be configured for pumping the second fluid supply **28** to transfer the second fluid supply **28**. In some embodiments, the first pump **36** and/or the second pump **38** can be a progressive cavity pump or a centrifugal pump, however, it is contemplated that other suitable types of pumps can be used. Additionally, as discussed further below, in some embodiments, the apparatus can be provided with a single pump that can pump a single fluid supply into a first fluid supply **16** and a second fluid supply **28**.

[0064] As depicted in FIGS. **1** and **2**, the apparatus **10** can also include a component feed system **40**. The component feed system **40** can include a component supply area **42** for receiving a supply of a component **44** as shown in the partial cut-away portion of the component supply area **42** illustrated in FIG. **2**. The component feed system **40** can also include an outlet conduit **46**. The outlet conduit **46** can be circular in cross-sectional shape or can be configured in a rectangular fashion such as to form a slot. The component feed system **40** can also include a hopper **48**. The hopper **48** can be coupled to the component supply area **42** and can be utilized for refiling the supply of the component **44** to the component supply area **42**.

[0065] In some embodiments, the component feed system **40** can include a bulk solids pump. Some examples of bulk solids pumps that may be used herein can include systems that utilize screws/augers, belts, vibratory trays, rotating discs, or other known systems for handling and discharging the supply of the component **44**. Other types of feeders can be used for the component feed system **40**, such as, for example, an ingredient feeder, such as those manufactured by Christy Machine & Conveyor, Fremont, Ohio. The component feed system **40** can also be configured as a conveyor system in some embodiments.

[0066] The component feed system **40** can also include a fluid control system **50**. The fluid control system **50** can be configured to control the gas entrainment into the fluid supply into which the supply of the component **44** is being placed. In some embodiments, the fluid control system **50** can include a housing **52**. The housing **52** can form a pressurized seal volume around the component feed system **40**. In other embodiments, the fluid control system **50** can be formed as an integral part to the structure component feed system **40** itself, such that a separate housing **52** surrounding the component feed system **40** may not be required. As depicted in FIGS. **1** and **2**, the fluid control system **50** can also include a bleed orifice **54** in some embodiments.

[0067] The supply of the component **44** can be in the form of a particulate and/or a fiber. In one embodiment as described herein, the supply of the component **44** can be superabsorbent material (SAM) in particulate form. In some embodiments, SAM can be in the form of a fiber. Of course, other types of components, as described further below, are also contemplated as being utilized in the apparatus **10** and methods as described herein. The component feed system **40** as described herein can be particularly beneficial for a supply of component **44** that is most suitably maintained in a dry environment with minimal of exposure to fluid or foam utilized in the apparatus **10** and methods described herein.

[0068] Referring to FIGS. **1-3**, in some embodiments, the apparatus **10** and methods described herein can include a first mixing junction **56** and a second mixing junction **58**. In preferred embodiments, the first mixing junction **56** can be an eductor. The first mixing junction **56** can be in fluid communication with the outlet conduit **46** of the component feed system **40** and in fluid communication with the second fluid supply **28**. As depicted in FIG. **3**, the first mixing junction **56** can include a first inlet **60** and a second inlet **62**. The first inlet **60** can be in fluid communication with the supply of the component **44** via the outlet conduit **46**. The second inlet **62** can be in fluid communication with the second fluid supply **28**. The first mixing junction **56** can also include a discharge **64**.

[0069] In preferred embodiments, the first mixing junction **56** can be configured as a co-axial eductor. For example, in a preferred embodiment, the first mixing junction **56** can be configured such that the first inlet axis **66** of the first inlet **60** of the first mixing junction **56** is co-axial with the outlet axis **68** of outlet conduit **46** that provides the supply of the component **44**. The first mixing junction **56** can also be configured such that the discharge axis **70** of the discharge **64** is co-axial with the outlet axis **68** of the outlet conduit **46**. As such, the first mixing junction **56** can be configured such that the first inlet axis **66** of the first inlet **60** can be co-axial with the discharge axis **70** of the discharge **64** of the first mixing junction **56**. The second inlet **62** providing the second fluid supply **28** to the first mixing junction **56** can be set up to enter the first mixing junction **56** on a side of the first mixing junction **56**. This configuration of having the supply of the component **44** be delivered in the first inlet **60** in a co-axial fashion to the discharge axis **70**, rather than having the second fluid supply **28** entering at the first inlet **60**, is opposite of most eductor configurations that are mixing a fluid supply and a component using a motive force of the fluid supply, but provides advantages to the first mixing junction **56** as described herein.

[0070] When configured as an eductor, the first mixing junction **56** can mix the supply of the component **44** from the component feed system **40** with the second fluid supply **28**. By transferring the second fluid supply **28** into the first mixing junction **56** at the second inlet **62** and through the first mixing junction **56**, the second fluid supply **28** provides a motive pressure to the supply of the component **44**. The motive pressure can create a vacuum on the supply of the component **44** and the component feed system **40** to help draw the supply of the component **44** to mix and be entrained in the second fluid supply **28**. In some embodiments, the motive pressure can create a vacuum on the supply of the component **44** of less than 1.5 in Hg, however, in other embodiments, the motive pressure could create a vacuum on the supply of the component **44** of 5 in. Hg or more, or 10 in Hg or more.

[0071] The fluid control system **50** can help manage proper distribution and entrainment of the supply of the component **44** to the second fluid supply **28** and can help control entrainment of fluid within the second fluid supply **28** downstream of the component feed system **40**. For example, if there was no housing **52** surrounding the component feed system **40**, additional fluid (e.g., surrounding gas, such as air) may be entrained into the second fluid supply **28** as the supply of the component **44** is metered into the second fluid supply **28**. It may also be the case when the second fluid supply **28** creates a motive pressure on the component feed system **40**, the vacuum pulling on the supply of the component **44** may cause additional air to be entrained in the second fluid supply **28**. In some circumstances, entraining additional air in the second fluid supply **28** may be desired, however, in other circumstances, it may be desirable to control the gas content of the second fluid supply **28** while inputting the supply of the component **44** to the second fluid supply **28** at the first mixing junction **56**. For example, in some circumstances where the second fluid supply **28** is a foam, the amount of gas content in the foam may be desired to be kept relatively fixed as the foam passes through the first mixing junction **56**. Thus, the fluid control system **50** can help control the pressure on and the gas flow through the component feed system **40** to help prevent or at least control the amount of gas being entrained in the second fluid supply **28** when the supply of the component **44** is being mixed with the second fluid supply **28**, and can help counteract the motive pressure on the supply of the component **44** and the component feed system **40** created by the second fluid supply **28**.

[0072] In some embodiments, the fluid control system **50** can include sealing off the component feed system **40**. For example, as discussed above, the fluid control system **50** can include a housing **52** to provide a seal on the component feed system **40**. Sealing the component feed system **40** can help to prevent additional air entrainment in the second fluid supply **28** when the supply of the component **44** is introduced into the second fluid supply **28** in the first mixing junction **56**.

[0073] However, in some embodiments, it may be beneficial to also include additional capability to the fluid control system **50**. For example, in some embodiments, the fluid control system **50** can include a bleed orifice **54**. The bleed orifice **54** can be configured to bleed-in fluid flow, such as atmospheric air flow, to provide additional fluid flow control of the component feed system **40**. The bleed orifice **54** can bleed in gas flow (e.g., air flow) inside the housing **52** to help control the air flow and pressure within the housing **52** surrounding the component feed system **40**. It has been discovered that by providing a bleed-in orifice **54** to provide some bleed-in of atmospheric air flow to the component feed system **40**, back-splashing of the second fluid supply **28** in the first mixing junction **56** can be reduced or eliminated. Reducing back-splashing of the second fluid supply **28** in the first mixing junction **56** can help prevent the component feed system **40** from becoming clogged or needing to be cleaned, especially where the component feed system **40** may be delivering a dry particulate, such as SAM. Under other process conditions, it may be desirable to completely seal the component feed system **40** for similar reasons.

[0074] Additionally or alternatively, the fluid control system **50** can be configured to provide additional gas flow (e.g., air flow) and/or positive pressure to prevent back-filling of the component feed system **40** in some circumstances, such as if a downstream obstruction occurs in the apparatus **10** beyond the first mixing junction **56**. In such a case of an obstruction creating an increased pressure, the second fluid supply **28** may have a desire to back-fill the component feed system **40**. Back-filling of fluid into the component feed system **40** can be detrimental to processing, especially where the supply of the component **44** is a dry component, such as SAM. A fluid control system **50** configured to be able to provide positive pressure to the component feed system **40** can help prevent such back-filling of the component feed system **40**.

[0075] It is also contemplated that other additional aspects of a fluid control system **50** could be utilized to maintain the gas flow and pressure to a suitable level for the component feed system **40**, including, but not limited to, supplying vacuum to the component feed system **40** in addition to or alternative to the air bleed-in at the bleed orifice **54** and/or the positive pressure described above.

[0076] As depicted in FIG. **3**, in some embodiments, the first mixing junction **56** can also include a venturi section **72**. The venturi section **72** can be a necked region of the first mixing junction **56** that can increase the velocity of the second fluid supply **28** passing through the venturi section **72**, and thus, can increase the vacuum pressure created by the second fluid supply **28** on the supply of the component **44** in the component feed system **40** and can help entrain the supply of the component **44** within the second fluid supply **28**. In some embodiments, the distal end **74** of the outlet conduit **46** providing the supply of the component **44** to the first mixing junction **56** can be disposed in the venturi section **72**. The location of the distal end **74** of the outlet conduit **46** can be adjusted within the venturi section **72** as one way to control both the pressure of the second fluid supply **28** as it is discharged from the first mixing junction **56** and the component feed system **40**.

[0077] The first mixing junction **56** can also provide pressure control on the transfer of the second fluid supply **28** including the component **44** as it exits the discharge **64** of the first mixing junction **56** as compared to when the second fluid supply **28** enters the first mixing junction **56**. The second fluid supply **28** can be transferred at a second fluid pressure prior to the first mixing junction **56**. The second fluid supply **28** including the component from the supply of the component **44** can exit the discharge **64** of the first mixing junction **56** at a discharge pressure. The pressure difference between the second fluid pressure prior to the first mixing junction **56** and the discharge pressure can be controlled. In some embodiments, this pressure difference can be controlled by varying the flow rate of the second fluid supply **28**. In some embodiments, this pressure difference can be controlled by the location of the distal end **74** of the outlet conduit **46** in the venturi section **72** of the first mixing junction **56**. For example, if the distal end **74** of the outlet conduit **46** is moved further into the venturi section **72**, the area for the second fluid supply **28** to flow through the venturi section **72** is reduced, and thus, the supply pressure of the second fluid supply **28** is increased. If the distal end **74** of the outlet conduit **46** is moved further out of the venturi section **72** (i.e., back towards the component feed system **40**), the area for the second fluid supply **28** to flow through the venturi section **72** is increased, and thus, the supply pressure of the second fluid supply **28** entering the first mixing junction **56** is decreased as is the vacuum level on the component feed system **40**. In some embodiments, it is preferable to control the pressure difference between the second fluid pressure prior to the first mixing junction **56** and the discharge pressure to be less than or equal to 25 pounds per square inch (psi), or more preferably, less than 20 psi, or less than 15 psi, or less than 10 psi, or less than 5 psi.

[0078] Another feature of the first mixing junction **56** that can create enhanced mixing and transfer of the supply of the component **44** into the second fluid supply **28** in the first mixing junction **56** can be that the second inlet **62** providing the second fluid supply **28** is upstream of the distal end **74** of the outlet conduit **46** that provides the supply of the component **44** from the component feed system **40** to the first mixing junction **56**. With such a configuration, the second fluid supply **28** can enter the first mixing junction **56** upstream of the supply of the component **44** to prevent any of the supply of the component **44** from engaging or sticking on an internal surface of the first mixing junction **56**. Thus, in the embodiment depicted in FIG. **3**, the co-axial nature of the outlet axis **68** of the outlet conduit **46** and the discharge axis **70** of the first mixing junction **56** and the upstream entry of the second fluid supply **28** into the first mixing junction **56** can create an annular-shaped fluid protection around the entry of the supply of the component **44** as it is entrained in the second fluid supply **28** in the first mixing junction **56**.

[0079] It is to be noted that while a single outlet conduit **46** of the component feed system **40** and a single first mixing junction **56** is illustrated in FIGS. **1-3**, it is contemplated that the outlet conduit **46** can be split into two or more conduits to feed two or more first mixing junctions **56** for mixing the supply of the component **44** with the second fluid supply **28**. In such a configuration, the second fluid supply **28** can include as many conduits as there are first mixing junctions **56**. By having more than one outlet conduit **46** and more than one first mixing junction **56** to mix the supply of the component **44** with the second fluid supply **28**, a greater flow rate of the second fluid supply **28** including the component from the supply of the component **44** can be achieved.

[0080] In some embodiments, it is also contemplated that the first mixing junction **56** can be an eductor of different configuration other than a co-axial eductor as described above. For example, it is contemplated that the first mixing junction **56** can be an eductor that is shaped as a slot eductor.

[0081] Referring back to FIG. **1**, the apparatus **10** can include a second mixing junction **58** in some embodiments. The second mixing junction **58** can provide the functionality of mixing the second fluid supply **28** including the component from the supply of the component **44** with the first fluid supply **16**. As the second fluid supply **28** including the component from the supply of the component **44** exits the discharge **64** of the first mixing junction **56** it can be transferred to the second mixing junction **58**. The first fluid supply **16** can be delivered to the second mixing junction **58** by the first pump **36**. The second mixing junction **58** can mix the first fluid supply **16** and any of its components (e.g., fluid **18**, fibers **20**, surfactant **22**) with the second fluid supply **28** and any of its components (e.g., fluid **30**, surfactant **32**) and the component from the supply of the component **44** to provide a resultant slurry **76**. The resultant slurry **76** can be transferred from the second mixing junction **58** through a discharge **78** of the second mixing junction **58** and to a headbox **80**. In some embodiments, there can be a separation between the discharge **78** of the second mixing junction **58** and the headbox **80**, as depicted in FIG. **3**. However, in other embodiments, the discharge **78** of the second mixing junction **58** can be integral with the headbox **80**.

[0082] In one aspect, the discharge **78** comprises as plurality of tubes that inject the slurry into the headbox **80**. The use of a plurality of tubes can facilitate preservation of the foam. For example, multiple inlet tubes can assist in maintaining an inlet fluid velocity into the headbox **80**. The system, for instance, can include at least 2 tubes, at least 3 tubes, at least 4 tubes, at least 5 tubes and less than about 30 inlet tubes, such as less than about 20 inlet tubes, such as less than about 15 inlet tubes.

[0083] An alternative embodiment of an apparatus **110** and method of forming a substrate **12** is depicted in FIG. **4**A. FIG. **4**A has the same components as the apparatus **10** and method as described in FIGS. **1-3** unless noted herein. The apparatus **110** of FIG. **4**A only includes a first tank **14** for holding a first fluid supply **16**. The apparatus **110** and method of FIG. **4**A does not include a second tank **26** including a second fluid supply **28**. The first fluid supply **16** can include a supply of fluid **18**, a supply of fibers **20**, and a supply of surfactant **22**. The apparatus **110** can also include a component feed system **40**, a fluid control system **50**, and a mixing junction **56** as described above with respect to FIGS. **1-3**. Based on this configuration, the first pump **36** can transfer the first fluid supply **16** to the first mixing junction **56**. The component feed system **40** can transfer a supply of component **44** to the first mixing junction **56** as previously described. In preferred embodiments, the first mixing junction **56** can be an eductor, and more preferably, a co-axial eductor as described with respect to FIG. **3**. The first mixing junction **56** can mix the first fluid supply **16** with component from the supply of the component **44** and provide a resultant slurry **76** that exits the discharge **64** of the first mixing junction **56** and is transferred to the headbox **80**. In some embodiments, the discharge **64** of the first mixing junction **56** can be separate from the headbox **80**, however, in some embodiments, the discharge **64** of the first mixing junction **56** can be integral to the headbox **80**. In some embodiments, the first fluid supply **16** can include fluid **18** and surfactant **22** to be mixed with the supply of the component **44** to provide the resultant slurry **76**, but be free from any fibers. In other embodiments, the first fluid supply **16** can include fluid **18**, fibers **20**, and surfactant **22** to be mixed with the supply of the component **44** to provide the resultant slurry **76**.

[0084] Another alternative embodiment of an apparatus **210** and method for forming a substrate **12** is depicted in FIG. **4**B. The apparatus **10** can include a first pump **36** that can be in fluid communication with the first fluid supply **16**. The first fluid supply **16** can include a supply of the fluid **18** and surfactant **22**. The first fluid supply **16** can be split at junction **17**. The first fluid supply **16** can continue past two control valves **23**. The first fluid supply **16** can continue past one of the control valves **23** in conduit **19** and towards headbox **80**. A supply of fibers **20** can be added to the first fluid supply **16** past the control valve **23**. Preferably, the supply of fibers **20** can be provided to the first fluid supply **16** in a supply of fluid, such as a foam.

[0085] When the first fluid supply is split at junction **17**, the first fluid supply **16** can be pumped past a second control valve **23** in conduit **21** towards the first mixing junction **56**. The fluid supply in this conduit can be referred to as the second fluid supply **28**. The second fluid supply **28** can include a supply of fluid **18** and surfactant **22** (that is from the first fluid supply **16**). In some embodiments, it may be preferable to add a supply of fibers **20′** to the second fluid supply **28**, as illustrated in FIG. **4**B. Preferably, the supply of fibers **20′** can be provided to the first fluid supply **16** in a supply of fluid, such as a foam.
[0086] In the embodiment depicted in FIG. **4**B, the supply of the component **44** can be added to the second fluid supply **28** at the first mixing junction **56** as described above. The apparatus **210** can include an output **65** of the first mixing junction **56** including the component **44** downstream of the discharge **64** of the first mixing junction **64**. The supply of fluid and component **44** in the output **65** of the first mixing junction **56** can provide a first input **67** into the headbox **80**. The first fluid supply **16** can provide a second input **69** into the headbox **80**. The first input **67** can be separate from the second input **69** into the headbox **80**. For example, in some embodiments, the first input **67** including the component **44** can be separated from the second input **69** by a height directional divider **71** (also referred to as a lamellae), and thus, the fluid supplies **16**, **28** can be separated from one another for at least a portion of the headbox **80** as the fluid supplied **16**, **28** are transferred through the headbox **80** to provide the resultant slurry **76**. In doing so, the resultant slurry **76** can provide two different layers to provide a two-layered substrate **12**.
[0087] Yet another alternative embodiment is illustrated in FIG. **4**C. FIG. **4**C is similar to the configuration depicted in FIG. **2**, however, a bleed-in orifice **154** is provided in the configuration of FIG. **4**C that can provide controlled fluid flow to the supply of the component **44** after the component **44** enters the outlet conduit **46** of the component feed system **40**, but upstream of the first mixing junction **56**. Such a configuration can provide fluid (e.g., liquid, gas, or foam) to the supply of the component **44** to help control the entrainment of fluid within the second fluid supply **28** as the supply of the component **44** is mixed with the second fluid supply **28** in the first mixing junction **56**. For example, in one embodiment, adding a flow of foam in the bleed-in orifice **154** can help prevent additional gas (e.g., air) from entraining in the supply of the component **44** as it is mixed with the second fluid supply **28**.
[0088] Regardless of whether the apparatus **10**, **110**, **210** and method used for transferring the resultant slurry **76** is as described herein, or is another apparatus and/or method, a headbox **80** can be provided to further transfer the resultant slurry **76** to form a substrate **12**. As depicted in FIGS. **5-6**, the headbox **80** can have a machine direction **81** and a cross direction **83**. The machine direction **81** is in the direction of the transfer of the resultant slurry **76** through the headbox **80**. The resultant slurry **76** is not shown in FIGS. **5-6** for clarity purposes.
[0089] The headbox **80** can include at least one flow section **82**. In the embodiment of the headbox **80** depicted in FIGS. **5-6**, the headbox **80** includes one flow section **82**. As illustrated in FIGS. **5-6**, the flow section **82** can include four zones in the machine direction **81**.
[0090] The most upstream zone (in the machine direction **81**) of the flow section **82** can be the constriction zone **130**. The constriction zone **130** can have an initial height (t.sub.i). The height of the constriction zone **130** may constrict as the slurry **76** flows along the machine direction **81** to a slice height (t.sub.s). The constriction zone may have an arcing shape, e.g., the top surface **120** may have a concave shape and the bottom surface **100** may have a convex shape that together may produce an arcing shape for the side profile of the constriction zone **130**. It is believed that the arcing shape in the height direction **85** between the top surface **120** and the bottom surface **110** along the constriction zone **130** (along with the geometry of the constriction zone **130** in the plane defined by the machine direction **81** and cross direction **83**) may provide enhanced control of the flow of the resultant slurry **76** and can help reduce eddies, or other turbulence of the flow of the resultant slurry **76** through the constriction zone, further adding to the advantages noted above with respect to the components from the supply of the component **44**. For example, it is believed that

this arcing shape can provide a more consistent basis weight and fiber orientation across the cross direction **83** in the substrate **12** that is formed, particularly when used in a foam forming process.

[0091] The next zone downstream (in the machine diction **81**) in the flow section **82** can be the slice zone **140**. The slice zone **140** can have a slice length (l.sub.s) measured along the machine direction **81**. The slice zone **140** can have a slice height (t.sub.s). The slice height (t.sub.s) may be the same along the entire length of the slice zone **140** (i.e., the slice length (l.sub.s).

[0092] The next zone downstream (in the machine diction **81**) in the flow section **82** may be the expansion zone **150**. The expansion zone may have a beginning height equal to the slice height (t.sub.s). The height of the expansion zone **150** may expand as the slurry **76** flows along the machine direction **81** to an expansion height (t.sub.1).

[0093] As the slurry of fibers **76** is forced through the slice zone **140**. The slice zone **140** has a slice height (t.sub.s) and slice length (l.sub.s) that causes the slurry of fibers **76** to rapidly increase in velocity and flow rate. The slurry of fibers **76** then exits the slice zone **140** and discharges into the expansion zone **150**. The rapid increase in velocity followed by a significant decrease in velocity of the slurry of fibers **76** causes significant turbulence to occur in the expansion zone **150** causing mixing of the fibers. Through this process, the orientation of the fibers, as opposed to only being oriented in the machine direction **81**, becomes much more random. Consequently, fiber orientation in the machine direction **81** can be the same or similar to the fiber orientation in the cross direction **83**. After exiting the slice zone **140**, the slurry of fibers **76** is then drained in the forming zone **160** for preserving and locking in the fiber orientation. In this manner, webs can be produced that have physical properties in the machine direction **81** that are very similar to physical properties in the cross direction **83**.

[0094] As explained above, the slurry of fibers **76** is accelerated in flow rate and velocity through the slice zone **140** and then discharged into an expansion zone **150** that has an expansive volume allowing the foamed suspension of fibers to rapidly decrease in velocity and flow rate causing turbulent flow within the fluid and resulting in random fiber orientation. Turbulent flow refers to flow of the foamed suspension in which the fluid undergoes irregular fluctuations, or mixing, in contrast to laminar flow in which the fluid moves in smooth paths or layers. For instance, the foamed suspension of fibers can undergo turbulent flow within the expansion zone **150** causing fluid swirls and eddies to be created that significantly enhance random distribution of the fibers within the foam.

[0095] The width of the headbox **80** over the flow section **82** can be uniform or can vary. In one aspect, for instance, the width of the flow section **82** gradually increases from the constriction zone **130** to the expansion zone **150**. In this manner, the slurry of fibers and other solid components can spread out for forming the nonwoven web. The headbox **80** has been found particularly well suited for not only creating uniform but random fiber distribution but also for creating uniform distribution of other solid components that may be contained in the slurry, such as superabsorbent particles. In one embodiment, the headbox **80** can increase in width in an amount greater than about 10%, such as in an amount greater than about 20%, such as in an amount greater than about 50%, such as in an amount greater than about 70%, such as in an amount greater than about 120%, such as in an amount greater than about 140%, such as in an amount greater than about 180%, such as in an amount greater than about 200%, and generally in an amount less than about 400%, such as in an amount less than about 300% over the length of the flow section **82**.

[0096] In one embodiment, the slurry of fibers **76** undergoes a hydraulic jump from the slice zone **140** to the expansion zone **150**. A hydraulic jump, for instance, can occur when a shallow, high velocity fluid meets slower moving fluid causing a rapid dissipation of kinetic energy. For example, when a fluid at high velocity discharges into a zone of lower velocity, a rather abrupt rise can occur in the fluid surface. The rapidly flowing fluid is abruptly slowed and increases in height which releases kinetic energy resulting in turbulence and/or the formation of eddies. For example, under some conditions, the transition of the fluid from fast velocity to slow velocity causes the fluid to curl back upon itself which, in the process of the present disclosure, causes the fibers to undergo intensive mixing and reorientation.

[0097] In one embodiment, flow of the slurry of fibers **76** reaches super-critical flow within the slice zone **140** followed by sub-critical flow within the expansion zone **150**. Super-critical flow occurs when flow is dominated by inertial forces as opposed to gravitational forces and can behave as rapid or unstable flow. Super-critical flow has a Froude number of greater than 1. Sub-critical flow, on the other hand, is dominated by gravitational forces and behaves in a slower stable way. As flow transitions from super-critical flow to sub-critical flow, a hydraulic jump can occur which represents a high energy loss, turbulent flow, and a random orientation of the fibers.

[0098] In one aspect of the present disclosure, the flow of the slurry of fibers and optionally as least one other solid component **76** through the slice zone **140** can operate at a desired Froude number. For instance, the Froude number of the foamed suspension of fibers can be greater than about 2, such as greater than about 5, such as greater than about 10, such as greater than about 15, such as greater than about 20, such as greater than about 25, such as greater than about 30, and generally less than about 50, such as less than about 40.

[0099] The next zone downstream (in the machine diction **81**) in the flow section **82** can be the formation zone **160**. The bottom surface of the expansion zone **160** may be a forming surface **94**. The formation zone **160** may have a beginning height equal to the expansion height (t.sub.1). The height of the formation zone **160** may constrict as the slurry **76** flows along the machine direction **81** to a formation height (t.sub.2).

[0100] In an embodiment of the present subject matter, the top surface **120** and the bottom surface **110** can be adjusted relative to one another in the height direction **85**. In this manner, one or more of the initial height (t.sub.i), slice height (t.sub.s), expansion height (t.sub.1), and formation height (t.sub.2) can be adjusted by moving the top surface **120** and the bottom surface **110** in relation to one another in the height direction **85**. In another embodiment of the present subject matter, at least a portion of the top surface **120** or the bottom surface **110** may be flexible. In this manner, one or more of the initial height (t.sub.i), slice height (t.sub.s), expansion height (t.sub.1), and formation height (t.sub.2) may be individually adjusted by deflecting flexible portion of the top surface **120** or the bottom surface **110** in the height direction **85**. In an embodiment, the flexible top surface **120** or flexible bottom surface **110** may be a lamellae or other similar structure.

[0101] The dimensions of the different features of the headbox **80** can vary depending upon the particular application and the desired result. In addition, the dimensions as described above can be varied by adjusting different components in the system, such as by moving the top surface **120** in relation to the bottom surface **110**. For exemplary purposes only, in one embodiment, the slice height (t.sub.s) is less than about 60%, such as less than about 50%, such as less than about 40%, such as less than about 30%, such as less than about 20%, such as less than about 10%, such as less than about 2% of the initial height (t.sub.i). The slice height (t.sub.s) is generally greater than about 0.1%, such as greater than about 0.5%, such as greater than about 1%, such as greater than about 5%, such as greater than about 10%, such as greater than about 20%, such as greater than about 30% of the initial height (t.sub.i). The slice height (t.sub.s) is generally less than about 60%, such as less than about 50%, such as less than about 40%, such as less than about 30%, such as less than about 25%, such as less than about 20%, such as less than about 15%, such as less than about 10% of the expansion height (t.sub.1). The slice height (t.sub.s) is generally greater than about 1%, such as greater than about 2%, such as greater than about 5%, such as greater than about 10%, such as greater than about 20%, such as greater than about 25%, such as greater than about 30%, such as greater than about 35%, such as greater than about 40% of the expansion height (t.sub.1).

[0102] As illustrated in FIG. **6**, the headbox may also include a top layer flow channel **170**. The top layer flow channel may be arranged above the flow section (in the height direction **85**). In an embodiment, the top layer flow channel **170** may deposit an additional layer on top of the resultant slurry **76** to form a multilayered product or laminate product. This additional layer may be the same material as that used to make the resultant slurry **76** or may be another material, as desired.

[0103] In an embodiment of the present subject matter, the geometry of the flow section **82** is adapted to keep the flow velocity of the slurry **76** high against any stationary surfaces to avoid agglomeration and backflow of fibers or other solid components, such as superabsorbent particles, that may be contained in the slurry. The geometry of the flow section **82** in the cross direction **83**, for example, may be as described in PCT Patent Application No. PCT/US2021/034722 (which is incorporated herein by reference in its entirety).

[0104] Referring back to FIGS. **1** and **4**, the apparatus **10**, **110**, **210** can also include a forming surface **94** onto which the resultant slurry **76** is deposited after exiting the outlet **92** of the headbox **80**. The forming surface **94** can be a foraminous sheet, such as a woven belt or screen, or any other suitable surface for accepting the resultant slurry **76**. As shown in FIG. **5**, the forming surface **94** can be inclined with respect to the horizontal. In some embodiments, the resultant slurry **76** may be deposited onto another pre-formed substrate that may be on top of the forming surface **94**. The apparatus **10**, **110** can also include a dewatering system **96** that can be configured to remove liquid from the resultant slurry **76** on the forming surface **94**. In some embodiments, the dewatering system **96** can be configured to provide a vacuum to the resultant slurry **76** to pull liquid from the resultant slurry **76**, and in doing so, can turn the resultant slurry **76** including the plurality of fibers **20** and the component **44** into a substrate **12**. In some embodiments, the apparatus **10**, **110**, **210** can also include a drying system **98**. The drying system **98** can be configured to further dry the resultant slurry **76** and/or the substrate **12**. In some embodiments, the apparatus **10**, **110**, **210** can include a winding system **99** that can be configured to wind the substrate **12** in a roll fashion. In other embodiments, the apparatus **10**, **110**, **210** can festoon the substrate **12**, or collect the substrate **12** in any other suitable configuration.

Foaming Fluid

[0105] The foam forming processes as described herein can include a foaming fluid. In some embodiments, the foaming fluid can comprise between about 85% to about 99.99% of the foam (by weight). In some embodiments, the foaming fluid used to make the foam can comprise at least about 85% of the foam (by weight). In certain embodiments, the foaming fluid can comprise between about 90% and about 99.9% % of the foam (by weight). In certain other embodiments, the foaming fluid can comprise between about 93% and 99.5% of the foam or even between about 95% and about 99.0% of the foam (by weight). In preferred embodiments, the foaming fluid can be water, however, it is contemplated that other processes may utilize other foaming fluids.

Foaming Surfactant

[0106] The foam forming processes as described herein can utilize one of more surfactants. The fibers and surfactant, together with the foaming liquid and any additional components, can form a stable dispersion capable of substantially retaining a high degree of porosity for longer than the drying process. In this regard, the surfactant is selected so as to provide a foam having a foam half life of at least 2 minutes, more desirably at least 5 minutes, and most desirably at least 10 minutes. A foam half life can be a function of surfactant types, surfactant concentrations, foam compositions/solid level and mixing power/air content in a foam. The foaming surfactant used in the foam can be selected from one or more known in the art that are capable of providing the desired degree of foam stability. In this regard, the foaming surfactant can be selected from anionic, cationic, nonionic and amphoteric surfactants provided they, alone or in combination with other components, provide the necessary foam stability, or foam half life. As will be appreciated, more than one surfactant can be used, including different types of surfactants, as long as they are compatible, and more than one surfactant of the same type. For example, a combination of a cationic surfactant and a nonionic surfactant or a combination of an anionic surfactant and a nonionic surfactant may be used in some embodiments due to their compatibilities. However, in some embodiments, a combination of a cationic surfactant and an anionic surfactant may not be satisfactory to combine due to incompatibilities between the surfactants.

[0107] Anionic surfactants believed suitable for use with the present disclosure include, without limitation, anionic sulfate surfactants, alkyl ether sulfonates, alkylaryl sulfonates, or mixtures or combinations thereof. Examples of alkylaryl sulfonates include, without limitation, alkyl benzene sulfonic acids and their salts, dialkylbenzene disulfonic acids and their salts, dialkylbenzene sulfonic acids and their salts, alkylphenol sulfonic acids/condensed alkylphenol sulfonic acids and their salts, or mixture or combinations thereof. Examples of additional anionic surfactants believed suitable for use in the present disclosure include alkali metal sulforicinates, sulfonated glyceryl esters of fatty acids such as sulfonated monoglycerides of coconut oil acids, salts of sulfonated monovalent alcohol esters such as sodium oleylisethianate, metal soaps of fatty acids, amides of amino sulfonic acids such as the sodium salt of oleyl methyl tauride, sulfonated products of fatty acids nitriles such as palmitonitrile sulfonate, alkali metal alkyl sulfates such as sodium lauryl sulfate, ammonium lauryl sulfate or triethanolamine lauryl sulfate, ether sulfates having alkyl groups of 8 or more carbon atoms such as sodium lauryl ether sulfate, ammonium lauryl ether sulfate, sodium alkyl aryl ether sulfates, and ammonium alkyl aryl ether sulfates, sulphuric esters of polyoxyethylene alkyl ether, sodium salts, potassium salts, and amine salts of alkylnapthylsulfonic acid. Certain phosphate surfactants including phosphate esters such as sodium lauryl phosphate esters or those available from the Dow Chemical Company under the tradename TRITON are also believed suitable for use herewith. A particularly desired anionic surfactant is sodium dodecyl sulfate (SDS).

[0108] Cationic surfactants are also believed suitable for use with the present disclosure for manufacturing some embodiments of substrates. In some embodiments, such as those including superabsorbent material, cationic surfactants may be less preferable to use due to potential interaction between the cationic surfactant(s) and the superabsorbent material, which may be anionic. Foaming cationic surfactants include, without limitation, monocarbyl ammonium salts, dicarbyl ammonium salts, tricarbyl ammonium salts, monocarbyl phosphonium salts, dicarbyl phosphonium salts, tricarbyl phosphonium salts, carbylcarboxy salts, quaternary ammonium salts, imidazolines, ethoxylated amines, quaternary phospholipids and so forth. Examples of additional cationic surfactants include various fatty acid amines and amides and their derivatives, and the salts of the fatty acid amines and amides. Examples of aliphatic fatty acid amines include dodecylamine acetate, octadecylamine acetate, and acetates of the amines of tallow fatty acids, homologues of aromatic amines having fatty acids such as dodecylanalin, fatty amides derived from aliphatic diamines such as undecylimidazoline, fatty amides derived from aliphatic diamines such as undecylimidazoline, fatty amides derived from disubstituted amines such as oleylaminodiethylamine, derivatives of ethylene diamine, quaternary ammonium compounds and their salts which are exemplified by tallow trimethyl ammonium chloride, dioctadecyldimethyl ammonium chloride, didodecyldimethyl ammonium chloride, dihexadecyl ammonium chloride, alkyltrimethylammonium hydroxides, dioctadecyldimethylammonium hydroxide, tallow trimethylammonium hydroxide, trimethylammonium hydroxide, methylpolyoxyethylene cocoammonium chloride, and dipalmityl hydroxyethylammonium methosulfate, amide derivatives of amino alcohols such as beta-hydroxylethylstearylamide, and amine salts of long chain fatty acids. Further examples of cationic surfactants believed suitable for use with the present disclosure include benzalkonium chloride, benzethonium chloride, cetrimonium bromide, distearyldimethylammonium chloride, tetramethylammonium hydroxide, and so forth.

[0109] Nonionic surfactants believed suitable for use in the present disclosure include, without limitation, condensates of ethylene oxide with a long chain fatty alcohol or fatty acid, condensates of ethylene oxide with an amine or an amide, condensation products of ethylene and propylene oxides, fatty acid alkylol amide and fatty amine oxides. Various additional examples of non-ionic surfactants include stearyl alcohol, sorbitan monostearate, octyl glucoside, octaethylene glycol monododecyl ether, lauryl glucoside, cetyl alcohol, cocamide MEA, monolaurin, polyoxyalkylene alkyl ethers such as polyethylene glycol long chain (12-14C) alkyl ether, polyoxyalkylene sorbitan ethers, polyoxyalkylene alkoxylate esters, polyoxyalkylene alkylphenol ethers, ethylene glycol propylene glycol copolymers, polyvinyl alcohol, alkylpolysaccharides, polyethylene glycol sorbitan monooleate, octylphenol ethylene oxide, and so forth.

[0110] The foaming surfactant can be used in varying amounts as necessary to achieve the desired foam stability and air-content in the foam. In certain embodiments, the foaming surfactant can comprise between about 0.005% and about 5% of the foam (by weight). In certain embodiments the foaming surfactant can comprise between about 0.05% and about 3% of the foam or even between about 0.05% and about 2% of the foam (by weight).

Fibers

[0111] As noted above, the apparatus **10**, **110** and methods described herein can include providing a fibers from a supply of fibers **18**. In some embodiments, the fibers can be suspending in a fluid supply **16**, **28** that can be a foam. The foam suspension of fibers can provide one or more supply of fibers. In some embodiments, the fibers utilized herein can include natural fibers and/or synthetic fibers. In some embodiments, a fiber supply **18** can include only natural fibers or only synthetic fibers. In other embodiments, a fiber supply **18** can include a mixture of natural fibers and synthetic fibers. Some fibers being utilized herein can be absorbent, whereas other fibers utilized herein can be non-absorbent. Non-absorbent fibers can provide features for the substrates that are formed from the methods and apparatuses described herein, such as improved intake or distribution of fluids.

[0112] A wide variety of cellulosic fibers are believed suitable for use herein. In some embodiments, the fibers utilized can be conventional papermaking fibers such as wood pulp fibers formed by a variety of pulping processes, such as kraft pulp, sulfite pulp, bleached chemithermomechanical pulp (BCTMP), chemithermomechanical pulp (CTMP), pressure/pressure thermomechanical pulp (PTMP), thermomechanical pulp (TMP), thermomechanical chemical pulp (TMCP), and so forth. By way of example only, fibers and methods of making wood pulp fibers are disclosed in U.S. Pat. No. 4,793,898 to Laamanen et al.; U.S. Pat. No. 4,594,130 to Chang et al.; U.S. Pat. No. 3,585,104 to Kleinhart; U.S. Pat. No. 5,595,628 to Gordon et al.; U.S. Pat. No. 5,522,967 to Shet; and so forth. Further, the fibers may be any high-average fiber length wood pulp, low-average fiber length wood pulp, or mixtures of the same. Examples of suitable high-average length pulp fibers include softwood fibers, such as, but not limited to, northern softwood, southern softwood, redwood, red cedar, hemlock, pine (e.g., southern pines), spruce (e.g., black spruce), and the like. Examples of suitable low-average length pulp fibers include hardwood fibers, such as, but not limited to, eucalyptus, maple, birch, aspen, and the like.

[0113] 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. In a particularly preferred embodiment refined fibers are utilized in the tissue web such that the total amount of virgin and/or high average fiber length wood fibers, such as softwood fibers, may be reduced.

[0114] Regardless of the origin of the wood pulp fiber, the wood pulp fibers preferably have an average fiber length greater than about 0.2 mm and less than about 3 mm, such as from about 0.35 mm and about 2.5 mm, or between about 0.5 mm to about 2 mm or even between about 0.7 mm and about 1.5 mm.

[0115] In addition, other cellulosic fibers that can be used in the present disclosure includes nonwoody fibers. As used herein, the term “non-wood fiber” generally refers to cellulosic fibers derived from non-woody monocotyledonous or dicotyledonous plant stems. Non-limiting examples of dicotyledonous plants that may be used to yield non-wood fiber include kenaf, jute, flax, ramie and hemp. Non-limiting examples of monocotyledonous plants that may be used to yield non-wood fiber include cereal straws (wheat, rye, barley, oat, etc.), stalks (corn, cotton, sorghum, Hesperaloe funifera, etc.), canes (bamboo, sisal, bagasse, etc.) and grasses (miscanthus. esparto, lemon, sabai, switchgrass, etc). In still other certain instances non-wood fiber may be derived from aquatic plants such as water hyacinth, microalgae such as *Spirulina*, and macroalgae seaweeds such as red or brown algae.

[0116] Still further, other cellulosic fibers for making substrates herein can include synthetic cellulose fiber types formed by spinning, including rayon in all its varieties, and other fibers derived from viscose or chemically-modified cellulose such as, for example, those available under the trade names LYOCELL and TENCEL.

[0117] In some embodiments, the non-woody and synthetic cellulosic fibers can have fiber length greater than about 0.2 mm including, for example, having an average fiber size between about 0.5 mm and about 50 mm or between about 0.75 and about 30 mm or even between about 1 mm and about 25 mm. Generally speaking, when fibers of relatively larger average length are being used, it may often be advantageous to modify the amount and type of foaming surfactant. For example, in some embodiments, if fibers of relatively larger average length are being used, it may be beneficial to utilize relatively higher amounts of foaming surfactant in order to help achieve a foam with the required foam half life.

[0118] Additional fibers that may be utilized in the present disclosure include fibers that are resistant to the forming fluid, namely those that are non-absorbent and whose bending stiffness is substantially unimpacted by the presence of forming fluid. As noted above, typically the forming fluid will comprise water. By way of non-limiting example, water-resistant fibers include fibers such as polymeric fibers comprising polyolefin, polyester (PET), polyamide, polylactic acid, or other fiber forming polymers. Polyolefin fibers, such as polyethylene (PE) and polypropylene (PP), are particularly well suited for use in the present disclosure. In some embodiments, non-absorbent fibers can be recycled fibers, compostable fibers, and/or marine degradable fibers. In addition, highly cross-linked cellulosic fibers having no-significant absorbent properties can also be used herein. In this regard, due to its very low levels of absorbency to water, water resistant fibers do not experience a significant change in bending stiffness upon contacting an aqueous fluid and therefore are capable of maintain an open composite structure upon wetting. The fiber diameter of a fiber can contribute to enhanced bending stiffness. For example, a PET fiber has a higher bending stiffness than a polyolefin fiber whether in dry or wet states. The higher the fiber denier, the higher the bending stiffness a fiber exhibits. Water resistant fibers desirably have a water retention value (WRV) less than about 1 and still more desirably between about 0 and about 0.5. In certain aspects, it is desirable that the fibers, or at least a portion thereof, include non-absorbent fibers.

[0119] The synthetic and/or water resistant fibers can have fiber length greater than about 0.2 mm including, for example, having an average fiber size between about 0.5 mm and about 50 mm or between about 0.75 and about 30 mm or even between about 1 mm and about 25 mm.

[0120] In some embodiments, the synthetic and/or water resistant fibers can have a crimped structure to enhance bulk generation capability of the foam formed fibrous substrate. For example, a PET crimped staple fiber may be able to generate a higher caliper (or result in a low sheet density) in comparison to a PET straight staple fiber with the same fiber diameter and fiber length.

[0121] In some embodiments, the total content of fibers, can comprise between about 0.01% to about 10% of the foam (by weight), and in some embodiments between about 0.1% to about 5% of the foam (by weight).

Binder

[0122] In some embodiments, a fluid supply **16**, **28** can include binder materials. Binder materials that may be used in the present disclosure can include, but are not limited to, thermoplastic binder fibers, such as PET/PE bicomponent binder fiber, and water-compatible adhesives such as, for example, latexes. In some embodiments, binder materials as used herein can be in powder form, for example, such as thermoplastic PE powder. Importantly, the binder can comprise one that is water insoluble on the dried substrate. In certain embodiments, latexes used in the present disclosure can be cationic or anionic to facilitate application to and adherence to cellulosic fibers that can be used herein. For instance, latexes believed suitable for use include, but are not limited to, anionic styrene-butadiene copolymers, polyvinyl acetate homopolymers, vinyl-acetate ethylene copolymers, vinyl-acetate acrylic copolymers, ethylene-vinyl chloride copolymers, ethylene-vinyl chloride-vinyl acetate terpolymers, acrylic polyvinyl chloride polymers, acrylic polymers, nitrile polymers, as well as other suitable anionic latex polymers known in the art. Examples of such latexes are described in U.S. Pat. No. 4,785,030 to Hager, U.S. Pat. No. 6,462,159 to Hamada, U.S. Pat. No. 6,752,905 to Chuang et al. and so forth. Examples of suitable thermoplastic binder fibers include, but are not limited to, monocomponent and multi-component fibers having at least one relatively low melting thermoplastic polymer such as polyethylene. In certain embodiments, polyethylene/polypropylene sheath/core staple fibers can be used. Binder fibers may have lengths in line with those described herein above in relation to the synthetic cellulosic fibers.

[0123] Binders in liquid form, such as latex emulsions, can comprise between about 0% and about 10% of the foam (by weight). In certain embodiments, the non-fibrous binder can comprise between about 0.1% and 10% of the foam (by weight) or even between about 0.2% and about 5% or even between about 0.5% and about 2% of the foam (by weight). Binder fibers, when used, may be added proportionally to the other components to achieve the desired fiber ratios and structure while maintaining the total solids content of the foam below the amounts stated above. As an example, in some embodiments, binder fibers can comprise between about 0% and about 50% of the total fiber weight, and more preferably, between about 5% to about 40% of the total fiber weight in some embodiments.

Foam Stabilizers

[0124] In some embodiments, if a fluid supply **16**, **28** is configured as a foam the foam may optionally also include one or more foam stabilizers known in the art and that are compatible with the components of the foam and further do not interfere with the hydrogen bonding as between the cellulosic fibers. Foam stabilizing agents believed suitable for use in the present disclosure, without limitation, one or more zwitterionic compounds, amine oxides, alkylated polyalkylene oxides, or mixture or combinations thereof. Specific examples of foam stabilizers includes, without limitation, cocoamine oxide, isononyldimethylamine oxide, n-dodecyldimethylamine oxide, and so forth.

[0125] In some embodiments, if utilized, the foam stabilizer can comprise between about 0.01% and about 2% of the foam (by weight). In certain embodiments, the foam stabilizer can comprise between about 0.05% and 1% of the foam or even between about 0.1 and about 0.5% of the foam (by weight).

Components

[0126] In the methods as described herein, the foam forming process can include adding one or more components as additional additives that will be incorporated into the substrate **12**. For example, one additional additive that can be added during the formation of the substrates **12** as described herein can be a superabsorbent materials (SAM). SAM is commonly provided in a particulate form and, in certain aspects, can comprise polymers of unsaturated carboxylic acids or derivatives thereof. These polymers are often rendered water insoluble, but water swellable, by crosslinking the polymer with a di- or polyfunctional internal crosslinking agent. These internally cross-linked polymers are at least partially neutralized and commonly contain pendant anionic carboxyl groups on the polymer backbone that enable the polymer to absorb aqueous fluids, such as body fluids. Typically, the SAM particles are subjected to a post-treatment to crosslink the pendant anionic carboxyl groups on the surface of the particle. SAMs are manufactured by known polymerization techniques, desirably by polymerization in aqueous solution by gel polymerization. The products of this polymerization process are aqueous polymer gels, i.e., SAM hydrogels that are reduced in size to small particles by mechanical forces, then dried using drying procedures and apparatus known in the art. The drying process is followed by pulverization of the resulting SAM particles to the desired particle size. Examples of superabsorbent materials include, but are not limited to, those described in U.S. Pat. No. 7,396,584 Azad et al., U.S. Pat. No. 7,935,860 Dodge et al., US2005/5245393 to Azad et al., US2014/09606 to Bergam et al., WO2008/027488 to Chang et al. and so forth. In addition, in order to aid processing, the SAM may be treated in order to render the material temporarily non-absorbing during the formation of the foam and formation of the highly-expanded foam. For example, in one aspect, the SAM may be treated with a water-soluble protective coating having a rate of dissolution selected such that the SAM is not substantially exposed to the aqueous carrier until the highly-expanded foam has been formed and drying operations initiated. Alternatively, in order to prevent or limit premature expansion during processing, the SAM may be introduced into the process at low temperatures.

[0127] In some embodiments incorporating SAM, the SAM can comprise between about 0% and about 40% of the foam (by weight). In certain embodiments, SAM can comprise between about 1% and about 30% of the foam (by weight) or even between about 10% and about 30% of the foam (by weight).

[0128] Other additional agents can include one or more wet strength additives that can be added to the foam or fluid supply **16**, **28** in order to help improve the relative strength of the ultra-low density composite cellulosic material. Such strength additives suitable for use with paper making fibers and the manufacture of paper tissue are known in the art. Temporary wet strength additives may be cationic, nonionic or anionic. Examples of such temporary wet strength additives include PAREZ™ 631 NC and PAREZ® 725 temporary wet strength resins that are cationic glyoxylated polyacrylamides available from Cytec Industries, located at West Paterson, N.J. These and similar resins are described in U.S. Pat. No. 3,556,932 to Coscia et al. and U.S. Pat. No. 3,556,933 to Williams et al. Additional examples of temporary wet strength additives include dialdehyde starches and other aldehyde containing polymers such as those described in U.S. Pat. No. 6,224,714 to Schroeder et al.; U.S. Pat. No. 6,274,667 to Shannon et al.; U.S. Pat. No. 6,287,418 to Schroeder et al.; and U.S. Pat. No. 6,365,667 to Shannon et al., and so forth.

[0129] Permanent wet strength agents comprising cationic oligomeric or polymeric resins may also be used in the present disclosure. Polyamide-polyamine-epichlorohydrin type resins such as KYMENE **557**H sold by Solenis are the most widely used permanent wet-strength agents and are suitable for use in the present disclosure. Such materials have been described in the following U.S. Pat. No. 3,700,623 to Keim; U.S. Pat. No. 3,772,076 to Keim; U.S. Pat. No. 3,855,158 to Petrovich et al.; U.S. Pat. No. 3,899,388 to Petrovich et al.; U.S. Pat. No. 4,129,528 to Petrovich et al.; U.S. Pat. No. 4,147,586 to Petrovich et al.; U.S. Pat. No. 4,222,921 to van Eenam and so forth. Other cationic resins include polyethylenimine resins and aminoplast resins obtained by reaction of formaldehyde with melamine or urea. Permanent and temporary wet strength resins may be used together in the manufacture of composite cellulosic products of the present disclosure. Further, dry strength resins may also optionally be applied to the composite cellulosic webs of the present disclosure. Such materials may include, but are not limited to, modified starches and other polysaccharides such as cationic, amphoteric, and anionic starches and guar and locust bean gums, modified polyacrylamides, carboxymethylcellulose, sugars, polyvinyl alcohol, chitosan, and the like.

[0130] If used, such wet and dry strength additives can comprise between about 0.01 and about 5% of the dry weight of cellulose fibers. In certain embodiments, the strength additives can comprise between about 0.05% and about 2% of the dry weight of cellulose fibers or even between about 0.1% and about 1% of the dry weight of cellulose fibers.

[0131] Still other additional components may be added to the foam so long as they do not significantly interfere with the formation of the highly-expanded stable foam, the hydrogen bonding as between the cellulosic fibers or other desired properties of the web. As examples, additional additives may include one or more pigments, opacifying agents, anti-microbial agents, pH modifiers, skin benefit agents, odor absorbing agents, fragrances, thermally expandable microspheres, foam particles (such as, pulverized foam particles), and so forth as desired to impart or improve one or more physical or aesthetic attributes. In certain embodiments the composite cellulosic webs may include skin benefit agents such as, for example, antioxidants, astringents,

conditioners, emollients, deodorants, external analgesics, film formers, humectants, hydrotropes, pH modifiers, surface modifiers, skin protectants, and so forth.
[0132] When employed, miscellaneous components desirably comprise less than about 2% of the foam (by weight) and still more desirably less than about 1% of the foam (by weight) and even less than about 0.5% of the foam (by weight).
[0133] In some embodiments, the solids content, including the fibers or particulates contained herein, desirably comprise no more than about 40% of the foam. In certain embodiments the cellulosic fibers can comprise between about 0.1% and about 5% of the foam or between about 0.2 and about 4% of the foam or even between about 0.5% and about 2% of the foam.
[0134] The methods and apparatuses **10**, **110**, **210** as described herein can be beneficial for forming one or more components of personal care products. For example, in one embodiment, the substrates **12** described herein can be an absorbent core for an absorbent article, such as, but not limited to, a diaper, adult incontinence garment, or feminine care product. The substrates **12** as described herein may also be beneficial for using in other products, such as, but not limited to facial tissues, wipes, and wipers.
Embodiments
[0135] Embodiment 1: A headbox including a machine direction, a cross direction, and a height direction, the headbox comprising at least one flow section, the at least one flow section comprising: a bottom surface; a top surface, the top surface being opposite the bottom surface in the height direction; wherein the at least one flow section comprises in order in the machine direction: i) a constriction zone; ii) a slice zone; iii) an expansion zone; and iv) a formation zone, wherein the constriction zone has an initial height (t.sub.i) and the height constricts in the machine direction to a slice height (t.sub.s); wherein in the slice zone is in fluid communication with a downstream end of the constriction zone and has a slice length (l.sub.s) in the machine direction and a height equal to the slice height (t.sub.s) over the slice length (l.sub.s); wherein the expansion zone is in fluid communication with a downstream end of the slice zone and has an initial height equal to the slice height (t.sub.s) and the height expands in the machine direction to an expansion height (t.sub.1); and wherein the formation zone is in fluid communication with a downstream end of the expansion zone and has an initial height equal to the expansion height (t.sub.1) and the height constricts in the machine direction to a formation height (t.sub.2).
[0136] Embodiment 2: The headbox of embodiment 1, wherein the bottom surface and the top surface are adjustable in relation to each other.
[0137] Embodiment 3: The headbox of any one of the proceeding embodiments, wherein at least a portion of the top surface is flexible.
[0138] Embodiment 4: The headbox of any one of the proceeding embodiments, wherein the top surface comprises a lamellae.
[0139] Embodiment 5: The headbox of any one of the proceeding embodiments, wherein one or more of the initial height (t.sub.i), the slice height (t.sub.s), the expansion height (t.sub.1), and the formation height (t.sub.2) are individually adjustable.
[0140] Embodiment 6: The headbox of any one of the proceeding embodiments, further comprising at least one top layer flow channel separated from and arranged above the at least one flow section in the height direction.
[0141] Embodiment 7: The headbox of any one of the proceeding embodiments, wherein the at least one flow section comprises a first flow section and a second flow section.
[0142] Embodiment 8: The headbox of any one of the proceeding embodiments, wherein the first flow section and the second flow section are spaced apart from one another in the cross direction.
[0143] Embodiment 9: The headbox of any one of the proceeding embodiments, wherein the bottom surface in the formation zone is a forming surface and the forming surface is inclined in relation to a horizontal.
[0144] Embodiment 10: A process for producing a web comprising: depositing a slurry of fibers

into a constriction zone; flowing the slurry of fibers from the constriction zone through a slice zone and into an expansion zone, the slurry of fibers having a fluid flow rate and the slice zone having a height (t.sub.s) and length (l.sub.s) such that the slurry of fibers undergoes turbulent flow within the expansion zone; flowing the slurry of fibers from the expansion zone into a formation zone the slurry being conveyed on a moving forming surface; draining fluids from the slurry of fibers through the forming surface within the formation zone to form an embryonic web; and drying the embryonic web.
[0145] Embodiment 11: The process of claim **10**, wherein the slice zone comprises a slot that extends along a width slice zone.
[0146] Embodiment 12: The process of any one of the proceeding embodiments, wherein the slurry of fibers undergoes super-critical flow in the slice zone.
[0147] Embodiment 13: The process of any one of the proceeding embodiments, wherein the turbulent flow of the slurry of fibers within the expansion zone produces eddies that causes changes in the orientation of the fibers in the slurry.
[0148] All documents cited in the Detailed Description are, in relevant part, incorporated herein by reference; the citation of any document is not to be construed as an admission that it is prior art with respect to the present invention. To the extent that any meaning or definition of a term in this written document conflicts with any meaning or definition of the term in a document incorporated by references, the meaning or definition assigned to the term in this written document shall govern.
[0149] These and other modifications and variations to the present invention may be practiced by those of ordinary skill in the art, without departing from the spirit and scope of the present invention, which is more particularly set forth in the appended claims. In addition, it should be understood that aspects of the various embodiments may be interchanged both in whole or in part. Furthermore, those of ordinary skill in the art will appreciate that the foregoing description is by way of example only, and is not intended to limit the invention so further described in such appended claims.

Claims

1. A headbox including a machine direction, a cross direction, and a height direction, the headbox comprising at least one flow section, the at least one flow section comprising: a bottom surface spaced from a top surface; and wherein the at least one flow section comprises in order in the machine direction: i) a constriction zone; ii) a slice zone; iii) an expansion zone; and iv) a formation zone, wherein the constriction zone has an initial height (ti) and the height constricts along the machine direction to a slice height (ts); wherein in the slice zone is in fluid communication with a downstream end of the constriction zone and has a slice length (ls) in the machine direction and a height equal to the slice height (ts) over the slice length (ls); wherein the expansion zone is in fluid communication with a downstream end of the slice zone and has a beginning height equal to the slice height (ts) and the height expands along the machine direction to an expansion height (t1); and wherein the formation zone is in fluid communication with a downstream end of the expansion zone and has a beginning height equal to the expansion height (t1) and the height constricts along the machine direction to a formation height (t2).
2. The headbox of claim 1, wherein the constriction zone gradually constricts along the machine direction.
3. The headbox of claim 1, wherein the expansion zone gradually increases in height downstream from the slice zone.
4. The headbox of claim 1, wherein the slice height (ts) is less than about 70%, such as less than about 50%, such as less than about 30%, such as less than about 20%, such as less than about 10%, such as less than about 5%, and greater than about 1%, such as greater than about 10%, such as greater than about 20% of the expansion height (t1).

5. The headbox of claim 1, wherein the bottom surface and the top surface are adjustable in relation to each other.
6. The headbox of claim 1, wherein at least a portion of the top surface is flexible.
7. The headbox of claim 1, wherein the top surface comprises a lamellae.
8. The headbox of claim 1, wherein one or more of the initial height (ti), the slice height (ts), the expansion height (t1), and the formation height (t2) are individually adjustable.
9. The headbox of claim 1, further comprising at least one top layer flow channel separated from and arranged above the at least one flow section in the height direction.
10. The headbox of claim 1, wherein the at least one flow section comprises a first flow section and a second flow section.
11. The headbox of claim 10, wherein the first flow section and the second flow section are spaced apart from one another in the cross direction.
12. The headbox of claim 1, wherein the bottom surface in the formation zone is a forming surface and the forming surface is inclined in relation to a horizontal.
13. A process for producing a web comprising: depositing a slurry of fibers and at least one other solid component into a constriction zone; flowing the slurry of fibers and at least one other solid component from the constriction zone through a slice zone and into an expansion zone, the slurry of fibers having a fluid flow rate and the slice zone having a height (ts) and length (ls) such that the slurry of fibers increases in velocity in the slice zone and undergoes turbulent flow within the expansion zone; flowing the slurry of fibers and at least one other solid component from the expansion zone into a formation zone, the slurry being conveyed on a moving forming surface; draining fluids from the slurry of fibers and at least one other solid component through the forming surface within the formation zone to form an embryonic web; and drying the embryonic web.
14. The process according to claim 13, wherein the at least one other solid component comprises superabsorbent particles.
15. The process of claim 14, wherein a density of the superabsorbent particles contained in the formed web varies by no more than about 10% over a cross direction of the web.
16. The process of claim 13, wherein the slice height (ts) is less than about 70%, such as less than about 50%, such as less than about 30%, such as less than about 20%, such as less than about 10%, such as less than about 5%, and greater than about 1%, such as greater than about 10%, such as greater than about 20% of the expansion height (t1).
17. The process of claim 13, further comprising the step of depositing another layer of fibers on the embryonic web to form a multi-layer sheet.
18. The process of claim 13, wherein the slice zone comprises a slot that extends along a width of the slice zone.
19. The process of claim 13, wherein the slurry undergoes super-critical flow in the slice zone.
20. The process of claim 13, wherein the turbulent flow of the slurry within the expansion zone produces eddies that causes slurry mixing.