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(54) HIGH LOFT, NONWOVEN WEB EXHIBITING EXCELLENT RECOVERY

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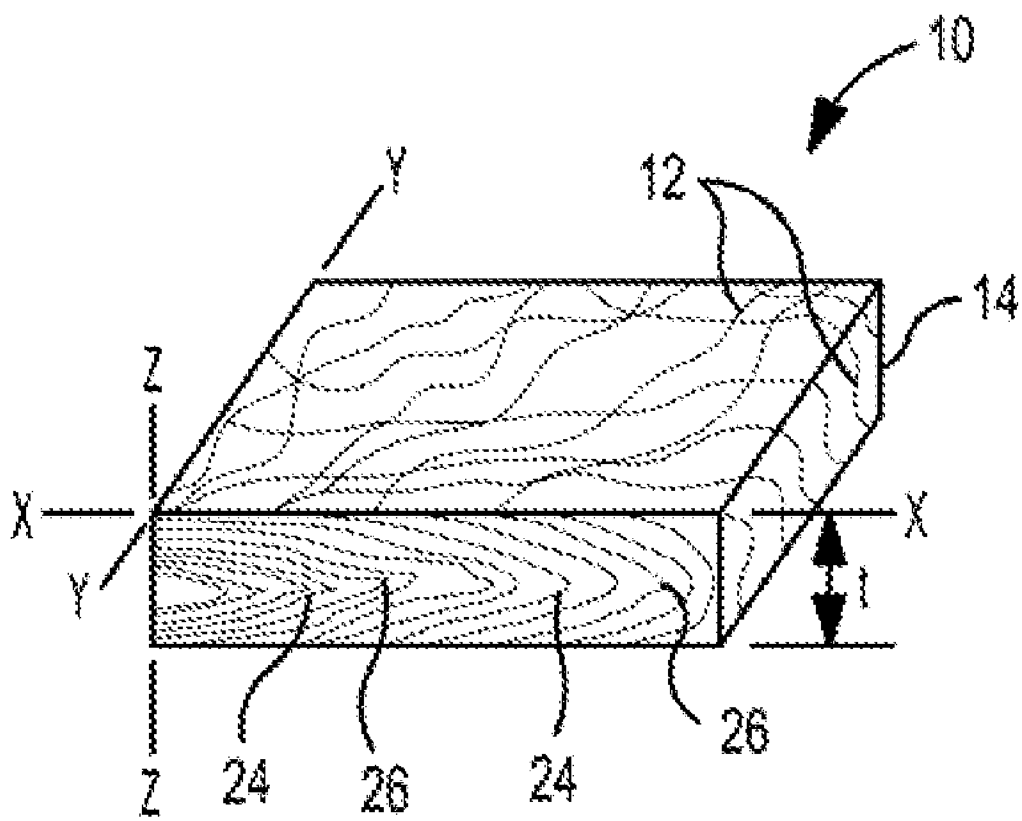
(57) **ABSTRACT**

A high loft, nonwoven web exhibiting excellent recovery.



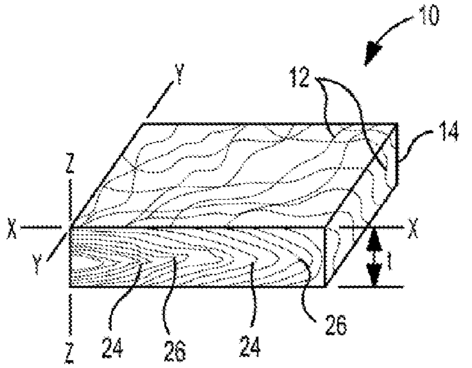


FIG. 1

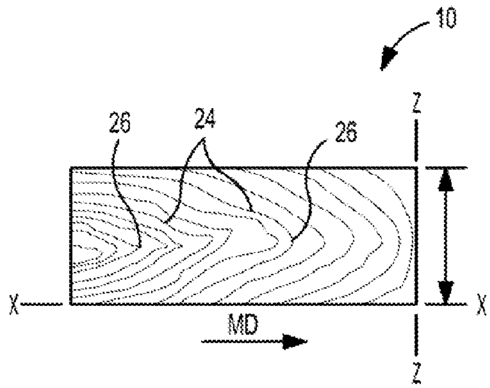


FIG. 2

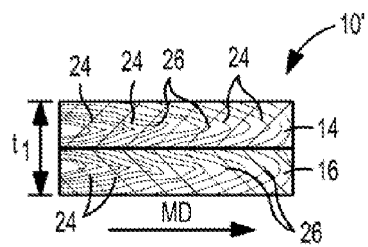


FIG. 3

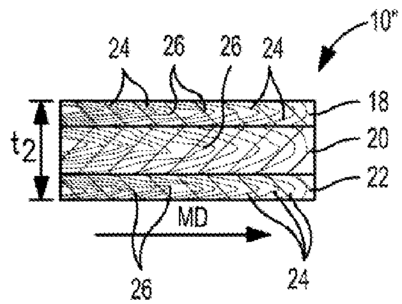


FIG. 4

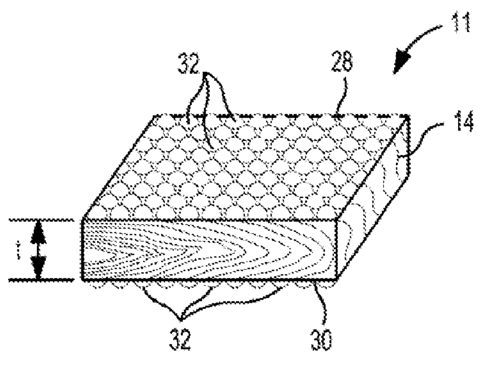


FIG. 5

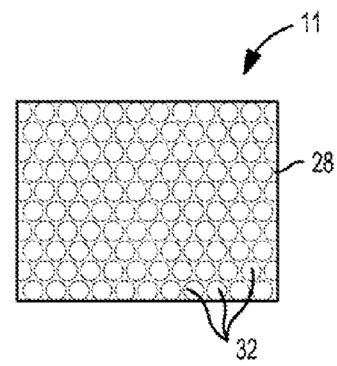


FIG. 6

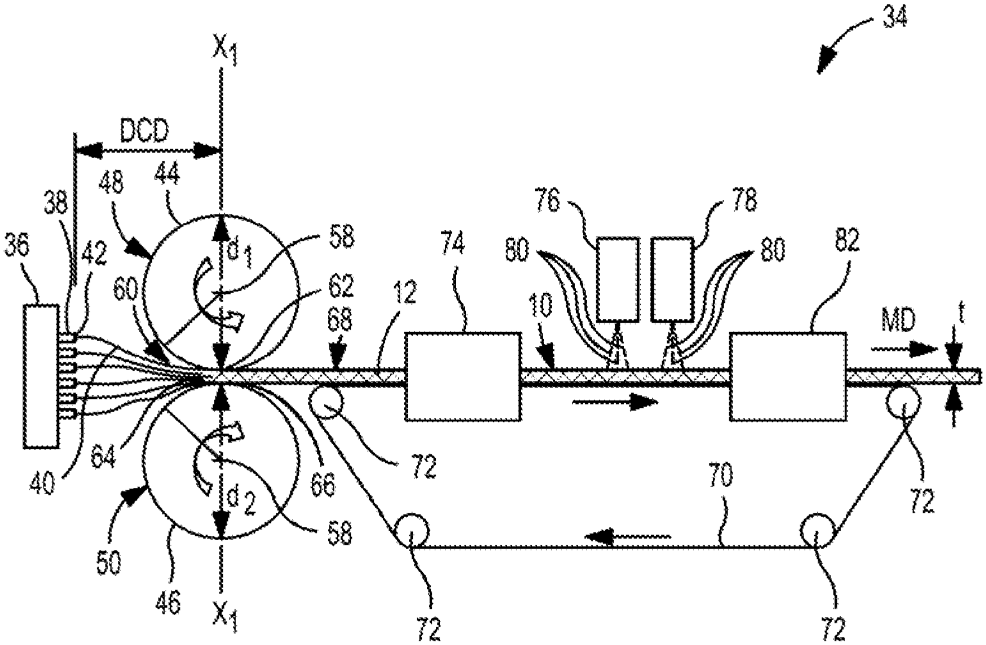
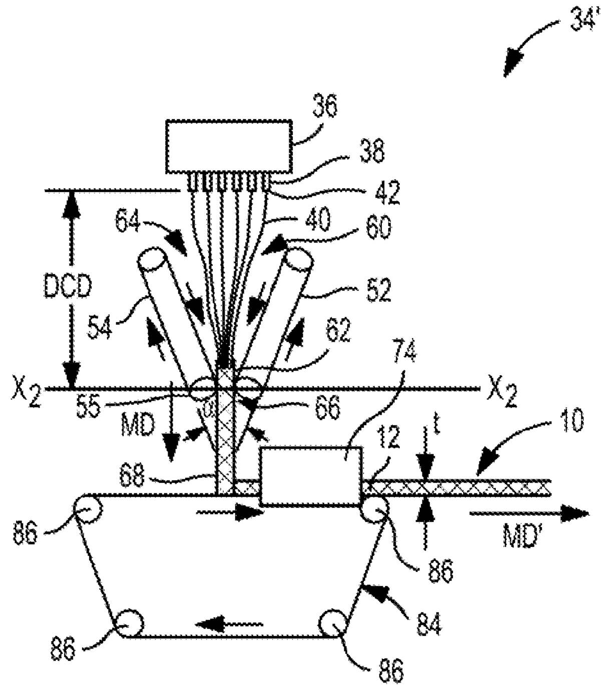

34
X1
DCD
38
48
44
36
42
60
58
62
68
12
74
76
78
80
80
10
82
MD
t
d1
d2
40
64
72
66
70
72
50
58
46
X1
72
72

FIG. 7


34'
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38
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52
54
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74
X2
X2
55
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MD
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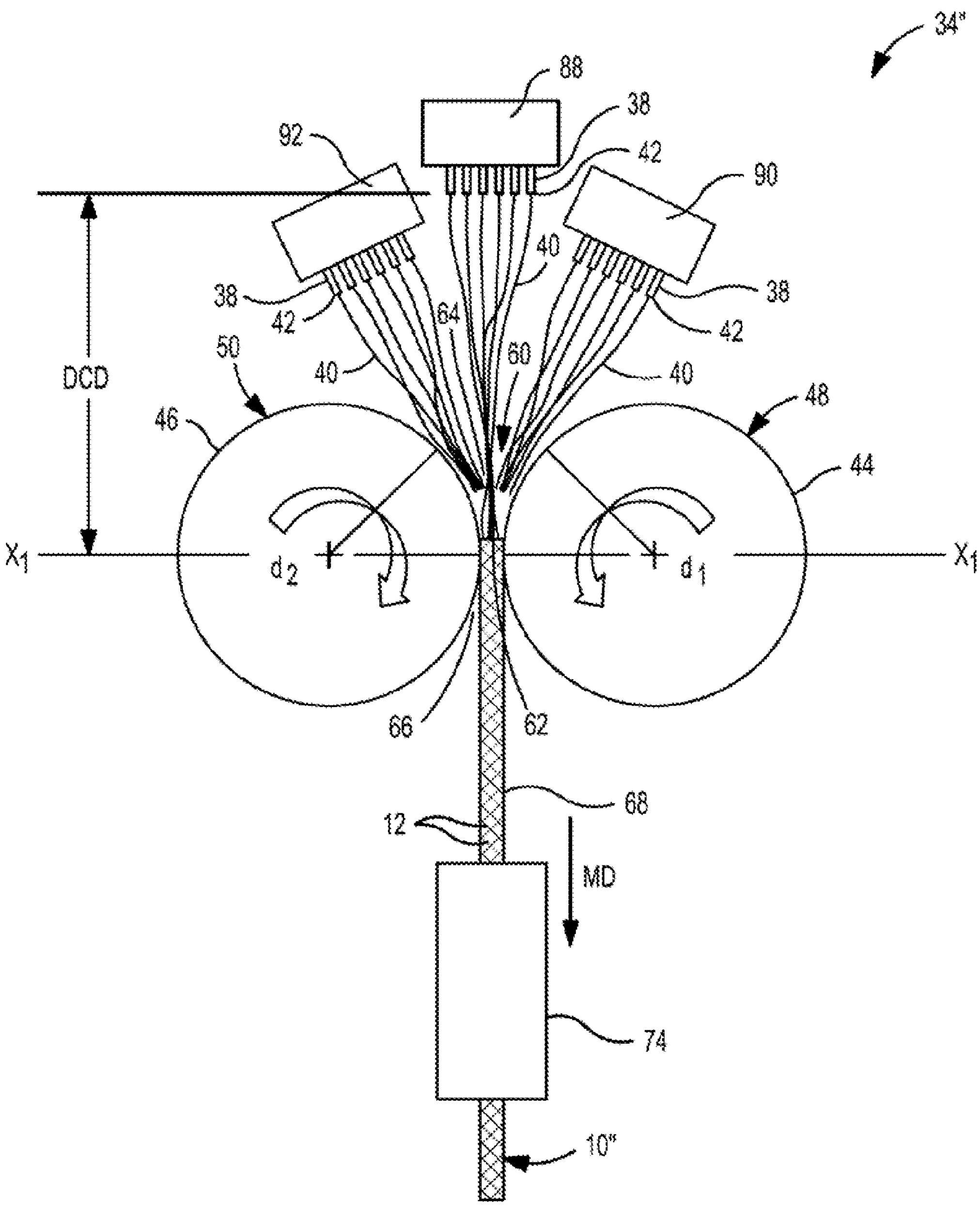
t
68
86
86
MD'
84
86
86

FIG. 8


34"
88
38
42
92
90
40
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64
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42
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50
DCD
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48
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44
X_1
d_2
d_1
X_1
66
62
68
12
MD
74
10"

FIG. 9

HIGH LOFT, NONWOVEN WEB EXHIBITING EXCELLENT RECOVERY

FIELD OF THE INVENTION

[0001] This invention relates to a high loft, nonwoven web exhibiting excellent recovery.

BACKGROUND OF THE INVENTION

[0002] Typically, polymeric fibers, formed by spunbonding, meltblowing or by some other extrusion process are collected downstream from an emitter, such as a die with a plurality of nozzles, on a horizontal oriented conveyor belt. Such processes tends to produce two-dimensional web where the fibers are oriented in the x and y directions since they are laid down in a horizontal plane. There are few if any fibers within the formed web that are oriented in the z-direction. Because of this, the finished web tends to lack recovery once it is compressed. This presents an issue when such finished webs need to be rolled up or stacked for transport by truck, or rail to a distant manufacturing, or distribution facility. If the webs are compacted or compressed during shipment, they lack the ability to recovery to their original thickness. In addition, once compacted or compressed, such webs tend to become hard and/or stiff and their pore structure may become less open. Furthermore, the drapeability of such webs can be diminished. Functionally, if a compacted or compressed web cannot recover to approximately its initial loft thickness after shipment, it can lose some of its thermal and/or acoustical insulation properties, thereby rendering the material less than desirable for this purpose.

[0003] Now, a high loft, nonwoven web, exhibiting excellent recovery, has been invented.

SUMMARY OF THE INVENTION

[0004] Briefly, this invention relates to a high loft, nonwoven web exhibiting excellent recovery.

[0005] The high loft, nonwoven web is a three dimensional structure with fibers oriented in the x, y and z directions. The web can be constructed as a single layer or be formed with two or more layers. The web has a thickness of less than about 250 millimeters and a basis weight of from between about 50 g/m^2 to about 3,000 g/m^2. The web can be bonded using a thermal bonder, a chemical bonder, a hydro-mechanical bonder, a mechanical bonder, or be left unbonded. A vertical cross-section of the web, when taken parallel to its machine direction, exhibits a plurality of snugly stacked, approximately V, U, or C-shaped structures, with each approximately V, U, or C-shaped shaped structure having an apex facing in the machine direction. The web has a recovery value of from between about 20% to about 99% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes according to the guidelines of the IST 120.2 (01).

[0006] An apparatus for producing a high loft, nonwoven web having a three dimensional structure with fibers oriented in the x, y and z directions is also taught. The apparatus includes a die having a plurality of nozzles each emitting a filament, and each of the plurality of nozzles having a distal end. A pair of moving surfaces is located from between about 10 cm to about 150 cm of the distal end of each of the plurality of nozzles. The pair of moving surfaces forms a convergent passage having an entry and an exit. The apparatus also includes a mechanism for depositing the plurality of filaments onto and between the pair of moving surfaces. The plurality of filaments is routed through the convergent passage in descending travel from the entry to the exit to form a 3-dimensional structure. The apparatus further includes a bonder located downstream of it and in vertically alignment with the pair of moving surfaces for bonding the 3-dimensional structure to create a high loft, nonwoven web with the filaments transformed into fibers oriented in the x, y and z directions. The web has a thickness of less than about 250 mm and a basis weight ranging from between about 50 g/m^2 to about 3,000 g/m^2. A vertical cross-section of the high loft, nonwoven web, when taken parallel to its machine direction, exhibits a plurality of snugly stacked, approximately V, U, or C-shaped structures, with each approximately V, U, or C-shaped structure having an apex facing in the machine direction. In other words, the approximately V or U shaped structure is rotated 90 degrees to a horizontal orientation with the apex of each facing to the right. The C-shaped structure is reversed in position so that the apex of each faces to the right. The high loft, nonwoven web has a recovery value ranging from between about 20% to about 99% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes.

[0007] A process for forming a high loft, nonwoven web includes the steps of introducing a molten polymer to a die having a plurality of nozzles. Emitting, ejecting or extruding the molten polymer through the plurality of nozzles to form a plurality of filaments. Air or gas streams are then used to facilitate movement and drawing/accelerating of the plurality of filaments. The filaments are directed towards a pair of moving surfaces located at a distance of from between about 10 cm to about 150 cm from the plurality of nozzles. The pair of moving surfaces forms a convergent passage having an entry and an exit. The plurality of filaments is deposited into the entry of the convergent passage. The plurality of filaments is then routed through the convergent passage in descending travel from the entry to the exit and between the pair of moving surfaces in a machine direction to form a 3-dimensional structure with the filaments transformed into fibers which are oriented in the x, y and z directions. Lastly, the 3-dimensional structure is bonded to form a high loft, nonwoven web having a thickness of less than about 250 millimeters and a basis weight ranging from between about 50 g/m^2 to about 3,000 g/m^2. A vertical cross-section of the high loft, nonwoven web, when taken parallel to its machine direction, exhibits a plurality of snugly stacked, approximately V, U, or C-shaped structures, with each approximately V, U, or C-shaped structure having an apex facing in the machine direction. The high loft, nonwoven web has a recovery value ranging from between about 20% to about 99% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes.

[0008] The general object of this invention is to provide high loft, nonwoven web exhibiting excellent recovery such that it can be compactly shipped without losing any material properties. A more specific object of this invention is to provide high loft, nonwoven web with good thermal insulation and/or acoustical insulation values.

[0009] Another object of this invention is to provide high loft, nonwoven web which can be used in the bedding, upholstery, filtration, foam replacement materials, and products utilizing cushioning materials.

[0010] A further object of this invention is to provide a high loft, nonwoven web exhibiting from between about 20% to about 99% recovery after compression, and such web exhibits a high porosity.

[0011] Still another object of this invention is to provide a high loft, nonwoven web exhibiting from between about 30% to about 95% recovery after compression.

[0012] Still further, an object of this invention is to provide a high loft, nonwoven web exhibiting from between about 40% to about 90% recovery after compression.

[0013] Other objects and advantages of the present invention will become more apparent to those skilled in the art in view of the following description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** is a perspective view of a high loft, nonwoven web of this invention showing a plurality of snugly stacked, approximate V, U or C-shaped structures, with each uniquely shaped structure having an apex facing in the machine direction of the web.

[0015] FIG. **2** is a schematic of a vertical cross-section of a section of a high loft, nonwoven web showing a plurality of snugly stacked, approximate V, U or C-shaped structures, with each uniquely shaped structure having an apex facing in the machine direction of the web.

[0016] FIG. **3** is a cross-sectional view of a two layer web.

[0017] FIG. **4** is a cross-sectional view of a multi-layer web.

[0018] FIG. **5** is a perspective view of an alternative embodiment of a high loft, nonwoven web depicting textured upper and lower surfaces

[0019] FIG. **6** is a schematic of the textured upper surface of the high loft, nonwoven web shown in FIG. **4**.

[0020] FIG. **7** is a schematic of an apparatus utilizing a pair of rotatable drums located immediately downstream of a die.

[0021] FIG. **8** is a schematic of an alternative apparatus utilizing a pair of angled conveyors located immediately downstream of a die.

[0022] FIG. **9** is a schematic of still another apparatus using a combination of a spunbond die positioned between first and second meltblown dies.

DETAILED DESCRIPTION OF THE INVENTION

[0023] Referring to FIGS. **1** and **2**, a high loft, nonwoven web **10** is shown. The high loft, nonwoven web **10** is a 3-dimensional structure with a plurality of fibers **12** oriented in the x, y and z directions. In FIG. **1**, X-X represents the longitudinal central axis, Y-Y represents the vertical central axis, and Z-Z represents the transverse central axis. By 'web" it is meant a fabric or material manufactured in sheet form. By "high loft" it is meant a low density, fibrous web characterized by a high ratio of thickness to weight per unit area. The fibers in the web **10** may be continuous or discontinuous, bonded or unbounded. Desirably, the fibers **12** are continuous and some of the fibers **12** are bonded. A high loft web has from between about 5% to about 60% solids by volume. By "nonwoven" it is meant a web, sheet or batt of natural and/or man-made fibers or filaments (excluding paper) that have not been converted into yarns, and that are bonded to each other by thermal, chemical, mechanical, hydro-mechanical, or by some other means known to those skilled in the art.

[0024] The high loft, nonwoven web **10** can be formed from a variety of materials. The high loft, nonwoven web **10** can be formed from man-made fibers. The fibers can be staple fibers. Typically, the high loft, nonwoven web **10** is formed from a polymer. The polymer can be selected from the group consisting of: polyolefins, polyesters, polyethylene terephthalates, polybutylene terephthalates, polycyclohexylene dimethylene terephthalates, polytrimethylene terephthalates, polymethyl methacrylates, polyamides, nylons, polyacrylics, polystyrenes, polyvinyls, polytetrafluoroethylenes, ultrahigh molecular weight polyethylenes, very high molecular weight polyethylenes, high molecular weight polyethylenes, polyether ether ketones, non-fibrous plasticized celluloses, polyethylenes, polypropylenes, polybutylenes, polymethylpentenes, low-density polyethylenes, linear low-density polyethylenes, high-density polyethylenes, polystyrenes, acrylonitrile-butadiene-styrenes, styrene-acrylonitriles, styrene-butadienes, styrene-maleic anhydrides, ethylene vinyl acetates, ethylene vinyl alcohols, polyvinyl chlorides, cellulose acetates, cellulose acetate butyrates, plasticized cellulosics, cellulose propionates, ethyl celluloses, natural fibers, any derivative thereof, any polymer blend thereof, any copolymer thereof or any combination thereof. Those skilled in the chemical arts may know of other polymers that can also be used to form the high loft, nonwoven web of this invention. It should be understood that the high loft, nonwoven web **10** of this invention is not limited to just those polymers identified above.

[0025] The high loft, nonwoven web **10** can be formed or manufactured using many different kinds and types of equipment and processes. Some commonly known technology which can be used to form the high loft, nonwoven web **10** include, but are not limited to: spinning processes such as meltblowing, spunbond, spunmelt, solution blowing, electrospinning. In addition, the high loft, nonwoven web **10** can be manufactured by a dry-laid process such as an air-lay process, a carding process or any combination of any two or more such processes where fibers are laid down at a nip between two moving surfaces. The manufactured high loft, nonwoven web **10** can be bonded or be unbounded. A bonding step adds strength and integrity to the finished web **10**.

[0026] By "spunbond" it is meant a process for producing strong fibrous nonwovens webs directly from thermoplastic polymers by attenuating the spun filaments using low temperature, high speed air while quenching the fibers near the spinnerette face. Individual fibers are then laid down randomly on a collection belt and are then conveyed to a bonder. The bonder gives the web strength and integrity. Fiber size is usually below 250 μm, the average fiber size is in the range of from between about 10 microns to about 50 microns and the fibers are very strong compared to meltblown fibers because of the molecular chain alignment that is achieved during the attenuating of the crystallized (solidified) filaments. A typical spunbond die has multiple rows of polymer nozzle holes. A typical melt flow rate is below about 500 grams/10 minutes.

[0027] By "spunmelt" it is meant a process where fibers are spun from molten polymers through a plurality of nozzles located in a die head connected to one or more extruders. A spunmelt process may include meltblowing and/or spunbonding.

[0028] By "meltblowing" it is meant a process where a plurality of molten polymer streams are attenuated using an elevated temperature, high speed gas stream. The gas can be air or other gases known to those skilled in the art. The attenuated fibers are then collected on a moving belt, conveyor or a dual drum collector. Typically, a meltblowing die has around 35 nozzles per inch, a row of spinnerettes and two inclined air or gas jets for attenuating the fiber streams. U.S. Pat. No. 4,380,570 and WO 2005/106,085 A1 teach meltblowing processes where multiple rows of polymer nozzles are surrounded by air nozzles and the streams flowing therefrom are aligned parallel to one another.

[0029] Still referring to FIGS. **1** and **2**, the high loft, nonwoven web **10** can be constructed as a single layer **14** of material. The high loft, nonwoven web **10** can be formed using equipment where air or gas is used to facilitate movement and drawing of the molten polymer through a plurality of nozzles into a plurality of filaments. Each of the plurality of filaments is emitted through a single nozzle.

[0030] Referring to FIGS. **3** and **4**, it should be understood that the high loft, nonwoven web **10'** can also be formed of two separate and distinct layers, **14** and **16**, see FIG. **3**, or the web **10"** can have multiple layers, see FIG. **4**. By "multiple layers" it is meant 3, 4, 5, 6, 7 or more separate and distinct layers. Some of the layers can be similar and/or identical in composition and characteristics to another layer, while one or more layers can vary in composition and/or characteristics from one or more of the remaining layers. In FIG. **4**, three separate and distinct layers **18**, **20** and **22** are present. It should be understood that the web **10**, consisting of a single layer **14**, the web **10'**, consisting of two layers **14** and **16**, or the web **10"**, consisting of three layers **18**, **20** and **22**, can be bonded to provide strength and integrity.

[0031] In FIG. **3**, the web **10'** is a two layer embodiment having an upper layer **14** and a lower layer **16**. In FIG. **4**, the web **10"** is a three layer embodiment having an upper layer **18**, a middle layer **20** and a lower layer **22**. When two or more layers are present in the finished nonwoven web, it should be understood that each layer can vary in the type of polymer it is made from. In addition, the characteristics of a given layer can vary. For example, the characteristics of one layer can be different from another layer. The thickness of each layer in the web **10"** can vary or be the same. The density of each layer in the web **10"** can also vary or be the same. The basis weight of each layer in the web **10"** can also vary or be the same.

[0032] Referring again to FIGS. **1** and **2**, the high loft, nonwoven web **10** is depicted as a single layer structure. The high loft, nonwoven web **10** has a thickness t which can vary in dimensions. Generally, the thickness t of the high loft, nonwoven web **10** can range from between about 5 millimeters (mm) to about 300 mm. Desirably, the thickness t of the high loft, nonwoven web is less than about 250 millimeters. More desirably, the thickness t of the high loft, nonwoven web **10** is less than about 200 mm. Even more desirably, the thickness t of the high loft, nonwoven web **10** is less than about 100 mm. Most desirably, the thickness t of the high loft, nonwoven web **10** is less than about 50 mm. When two or more layers are present in the finished web **10'** or **10"**, the overall thickness of the web **10'** or **10"** can double, triple, etc. depending upon how many layers are present.

[0033] The high loft, nonwoven web **10** can be formed with different basis weights. Generally, the basis weight of the high loft, nonwoven web **10** ranges from between about 50 grams per square meter (g/m^2) to about 3,000 g/m^2. Desirably, the basis weight of the high loft, nonwoven web **10** ranges from between about 750 grams per square meter (g/m^2) to about 2,500 g/m^2. More desirably, the basis weight of the high loft, nonwoven web **10** ranges from between about 100 grams per square meter (g/m^2) to about 1,000 g/m^2. Even more desirably, the basis weight of the high loft, nonwoven web **10** is less than about 600 g/m^2.

[0034] The high loft, nonwoven web **10** can also vary in density. Generally, the high loft, nonwoven web **10** has a density ranging from between about 10 kilograms per cubic meters (Kg/m^3) to about 250 Kg/m^3. Desirably, the high loft, nonwoven web **10** has a density ranging from between about 20 Kg/m^3 to about 200 Kg/m^3. More desirably, the high loft, nonwoven web **10** has a density ranging from between about 30 Kg/m^3 to about 150 Kg/m^3. Even more desirably, the high loft, nonwoven web **10** has a density ranging from between about 40 Kg/m^3 to about 100 Kg/m^3.

[0035] The high loft, nonwoven web **10** can be bonded or unbounded. Desirably, the high loft, nonwoven web **10** is bonded. Bonding generally imparts strength and integrity to the web **10**. Bonding can be performed using different type of equipment and processes known to those skilled in the art. Various bonders include: mechanical bonders such as needle bonding, hydro-mechanical bonders, also known as wet bonding, thermal bonders, which include through air bonding and oven thermal bonding and chemical bonding. Whichever type of bonder is utilized, some of the fibers **12**, **14**, **16**, **18**, **20** and **22** are bonded together to make the high loft, nonwoven web **10**, **10'** and **10"** stronger.

[0036] Furthermore, the high loft, nonwoven web **10** can be formed from polypropylene having a melt flow rate ranging from between about 4 g/10 min. to about 6,000 g/10 min at a temperature of 230° C. and at a pressure of 2.16 kg according to the teachings of ASTM D 1238 testing method. Desirably, the high loft, nonwoven web **10** can be formed from polypropylene having a melt flow rate ranging from between about 35 g/10 min. to about 2,500 g/10 min at a temperature of 230° C. and at a pressure of 2.16 kg. More desirably, the high loft, nonwoven web **10** can be formed from polypropylene having a melt flow rate ranging from between about 500 g/10 min. to about 2,000 g/10 min at a temperature of 230° C. and at a pressure of 2.16 kg. Most desirably, the high loft, nonwoven web **10** can be formed from polypropylene having a melt flow rate ranging from between about 500 g/10 min. to about 1,500 g/10 min at a temperature of 230° C. and at a pressure of 2.16 kg.

[0037] Referring again to FIG. **2**, the schematic clearly shows a vertical cross-section of the high loft, nonwoven web **10** taken parallel to the machine direction (MD). During formation of the high loft, nonwoven web **10**, the material advances from left to right. The leading edge of the high loft, nonwoven web **10** is to the right. The high loft, nonwoven web **10** exhibits a plurality of snugly stacked, approximately V, U or C-shaped structures **24**. These V, U or C-shaped structures **24** are also depicted in FIG. **1**. Each of the approximately V, U or C-shaped structures **24** has an apex **26** which faces in the machine direction (MD). In other words, the approximately V or U shaped structure is rotated 90 degrees to a horizontal orientation with the apex of each facing to the right. The C-shaped structure is reversed in position so that the apex of each faces to the right. This unique structure occurs because of the way the fibers **12** are laid down during formation. This unique structure is important for it gives the high loft, nonwoven web **10** a very high recovery value. The high loft, nonwoven web has a recovery value ranging from between about 20% to about 99% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes, according to the guidelines of the INDA Standard Test Method (IST 120.2 (01)). Desirably, the high loft, nonwoven web **10** has a recovery value ranging from between about 30% to about 95% according to the guidelines of the IST 120.2 (01). More desirably, the high loft, nonwoven web **10** has a recovery value ranging from between about 40% to about 90% according to the guidelines of the IST 120.2 (01). Even more desirably, the high loft, nonwoven web **10** has a recovery value ranging from between about 50% to about 80% according to the guidelines of the IST 120.2 (01).

[0038] It should be understood that each layer of the two layer web **10'**, shown in FIG. **3**, and each layer of the three layered web **10"**, shown in FIG. **4**, also exhibits this plurality of snugly stacked, approximately V, U or C-shaped structures **24** if they are laminated offline, but they will show one snugly stacked structured, approximately V, U or C shaped structured, if they are comingled simultaneously from different spinning heads as shown in FIG. **9**. This kind of comingled high loft structure could have different fiber size, different polymeric materials, and/or different fiber cross-section.

[0039] Referring again to FIG. **3**, the two layered web **10'** has a three dimensional structure with fibers oriented in the x, y and z directions. This two layer web **10'** has a thickness t_1 of from between about 5 millimeters to about 500 millimeters and a basis weight of from between about 50 g/m^2 to about 2,000 g/m^{2}' The two layered web **10'** does not have to be bonded but desirably is thermally or chemically bonded. Alternatively, the web **10'** could be mechanically or hydromechanically bonded. Each of the two layers, **14** and **16**, of the web **10'** exhibits a vertical cross-section, when taken parallel to the machine direction (MD) during manufacture of the two layered web **10'**, which exhibits a plurality of snugly stacked, approximately V, U or C-shaped structures **24**. Each of the approximately V, U or C-shaped structures **24** has an apex **26** facing in the machine direction (MD). In other words, the approximately V or U shaped structure is rotated 90 degrees to a horizontal orientation with the apex of each facing to the right. The C-shaped structure is reversed in position so that the apex of each faces to the right. The two layered web **10'** has a recovery value of from between about 20% to about 99% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes according to the guidelines of the IST 120.2 (01). Desirably, the two layered web **10'** has a recovery value ranging from between about 30% to about 95% according to the guidelines of the IST 120.2 (01). More desirably, the two layered web **10'** has a recovery value ranging from between about 40% to about 90% according to the guidelines of the IST 120.2 (01). Even more desirably, the two layered web **10'** has a recovery value ranging from between about 50% to about 80% according to the guidelines of the IST 120.2 (01).

[0040] It should be understood that the two layer web **10'** can be formed as two separate layers **14** and **16** from comingled fibrous materials where each layer has a different fiber size, is formed from a different material, has different fiber cross-sections, etc. Furthermore, the two layered web **10'** could be laminated to one or more layers. The additional layers could be a thermoplastic film, a film, another nonwoven material, paper, cardboard, etc.

[0041] Referring again to FIG. **4**, the three layered web **10"** has a three dimensional structure with fibers oriented in the x, y and z directions. This three layer web **10"** has a thickness t_2 of from between about 5 millimeters to about 750 millimeters and a basis weight of from between about 50 g/m^2 to about 2,000 g/m^2 The three layered web **10"** does not have to be bonded but desirably is thermally or chemically bonded. Alternatively, the web **10"** could be mechanically or hydromechanically bonded. Each of the three layers, **18**, **20** and **22**, of the web **10"** exhibits a vertical cross-section, when taken parallel to the machine direction (MD) during manufacture of the web **10"**, which exhibits a plurality of snugly stacked, approximately V, U or C-shaped structures **24**. Each of the approximately V, U or C-shaped structures **24** has an apex **26** facing in the machine direction (MD). In other words, the approximately V or U shaped structure is rotated 90 degrees to a horizontal orientation with the apex of each facing to the right. The C-shaped structure is reversed in position so that the apex of each faces to the right. The three layered web **10"** has a recovery value of from between about 20% to about 99% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes according to IST 120.2 (01). Desirably, the three layered web **10** has a recovery value ranging from between about 30% to about 95% according to IST 120.2 (01). More desirably, the three layered web **10** has a recovery value ranging from between about 40% to about 90% according to IST 120.2 (01). Even more desirably, the three layered web **10** has a recovery value ranging from between about 50% to about 80% according to IST 120.2 (01).

[0042] It should also be recognized that an additive can be incorporated into the high loft, nonwoven web **10**, **10'** or **10'**. The additive (not shown) can be applied to the high loft, nonwoven web **10**, **10'** or **10"** during manufacture. The additive can be applied in various ways, including but not limited to: being sprayed on, being sprinkled on, being extruded, being combined with, being painted on, being immersed, etc. The additive can be a gas, a liquid, a solid or a semi-solid. The additive can be selected from the group consisting of: a superabsorbent, absorbent particles, pulp fibers, polymers, nanoparticles, abrasive particulars, active particles, active compounds, ion exchange resins, zeolites, softening agents, plasticizers, ceramic particles pigments, dyes, flavorants, aromas, controlled release vesicles, binders, adhesives, tackifiers, surface modification agents, lubricating agents, emulsifiers, vitamins, peroxides, antimicrobials, deodorizers, fire retardants, flame retardants, antifoaming agents, anti-static agents, biocides, antifungals, degradation agents, stabilizing agents, conductivity modifying agents, or any combination thereof.

[0043] Referring now to FIGS. **5** and **6**, an alternative embodiment of high loft, nonwoven web **11** is shown having been formed as a single layer **14** with two major surfaces **28** and **30**. The two major surfaces **28** and **30** are aligned opposite to one another. In FIG. **5**, the two major surfaces include the upper surface **28** and the lower surface **30**. By "two major surfaces" it is meant the two surfaces of the web **11** which have the greatest surface area. The web **11** has two major surfaces, **28** and **30**, and both of these major surfaces **28** and **30** are textured. By "textured" it is meant a rough or grainy surface quality, as opposed to being smooth. The texture can be formed various ways during processing of the web **11**. In FIG. **5**, a plurality of protuberances **32** extends upward from the upper surface **28** and downward from the lower surface **30**. By "protuberance" it is meant a bulge, knob or swelling that protrudes outward. Alternatively, indentations, cavities or depressions could be formed in the upper and/or lower surfaces, **28** and **30** respectively, to obtain a similar textured effect. Desirably, at least one of the two major surfaces, **28** and **30** of the web **11** is textured. More desirably, both of the two major surfaces, **28** and **30** of a web **11** are textured.

Apparatus

[0044] Referring to FIG. **7**, an apparatus **34** is shown for producing a high loft, nonwoven web **10**, **10'**, **10"** or **11**. The apparatus **34** is shown being oriented in a horizontal configuration, although it could be arranged vertically or at some other angle relative to the vertical axis. The high loft, nonwoven web **10**, **10'**, **10"** or **11** has a three dimensional structure with fibers oriented in the x, y and z directions. The apparatus **34** includes a die **36** having a plurality of nozzles **38** each emitting, ejecting or extruding a filament **40**. Each of the plurality of nozzles **38** has a distal end **42**. The apparatus **34** can use air or gas to facilitate movement and drawing of the molten polymer from the plurality of nozzles **38** into a plurality of filaments. A pair of moving surfaces, **44** and **46**, is located from between about 10 centimeters (cm) to about 150 cm of the distal end **42** of each of the plurality of nozzles **38**. The pair of moving surfaces, **44** and **46**, can be a first rotatable drum **48** and a second rotatable drum **50**, as is shown in FIG. **7**. Alternatively, the pair of moving surfaces, **44** and **46**, can be a first conveyor belt **52** and a second conveyor belt **54**, as is shown in FIG. **8**. Other forms of moving surfaces, **44** and **46**, known to those skilled in the art can also be employed.

[0045] When the pair of moving surfaces, **44** and **46**, consists of a first rotatable drum **48** and a second rotatable drum **50**, the first rotatable drum **48** will have a diameter d_1 and the second rotatable drum **50** will have a diameter d_2 Desirably, the diameter d_1 is approximately equal to the diameter d_2. More desirably, the diameters d_1 and d_2 are identical. The first and second rotatable drums, **48** and **50** respectively, will be aligned parallel to one another on the same plane X_1-X_1. It should be understood that the apparatus **34** is horizontally oriented so that the filaments **40** will move from left to right in a machine direction (MD) between the first and second rotatable drums, **48** and **50** respectively.

[0046] Still referring to FIG. **7**, one can see that the first drum **48** rotates counterclockwise while the second drum **50** rotates clockwise. This specific rotation will cause the plurality of continuous filaments **40** to move in the machine direction (MD) away from the plurality of nozzles **38**. The speed of the first and second rotatable drums, **48** and **50** respectively, can vary. Desirably, each of the first and second rotatable drums, **48** and **50** respectively, will rotate at the same speed. Alternatively, one of the first and second rotatable drums, **48** and **50** respectively, could rotate at a different speed than the other drum and therefore a different cross-sectional structure may be produced in the machine direction such as S or S-like shape. The speed of the first and second rotatable drums, **48** and **50** respectively, should be adjusted according to the basis weight of the material that is being produced, the thickness of the desired web **10**, the kind of polymer being extruded, the polymer throughput through the plurality of nozzles **38**, etc.

[0047] The first and second rotatable drums, **48** and **50** respectively, can be operated at room temperature. Alternatively, the first and second rotatable drums, **48** and **50** respectively, could be operated at an elevated temperature or at a temperature below room temperature. Desirably, the first and second rotatable drums, **48** and **50** respectively, are operated at room temperature.

[0048] The first and second rotatable drums, **48** and **50** respectively, can be hollow cylinders with their outer peripheries covered with a forming wire or screen. The forming wire or screen can be produced from a variety of different materials known to those skilled in the art. For example, the forming wire or screen could be made from a synthetic material, such as polyethylene terephthalate (PET). Alternatively, the forming wire or screen could be made from: metal, steel, aluminum, a plastic, a thermoplastics, etc. The first and second rotatable drums, **48** and **50** respectively, could also be constructed out of various materials, such as wood, steel, cast iron, aluminum, etc. Another option is to cover the outer peripheries of the first and second rotatable drums, **48** and **50** respectively, with metal belts. The metal belts could be ferrous or non-ferrous. The metal belts could contain a plurality of apertures, openings or holes arranged in a predetermined pattern or could be randomly arranged. The size and shape of the apertures, openings or holes can vary. As is known to those skilled in the art, each of the first and second rotatable drums, **48** and **50** respectively, can be equipped with adjustable vacuum chamber, if desired. Sometimes, it is advantageous to slightly heat the outer peripheries of the first and second rotatable drums, **48** and **50** respectively; so that the incoming filaments **40** will more readily form onto them. The reason for this is that the open mesh design of a wire, screen or a metal belt containing apertures, openings or holes can form a specific texture or pattern onto the outer surfaces of the high loft, nonwoven web **10**, **10'**, **10"** or **11** that is being produced. Such texture or pattern may enhance the sound insulation and/or thermal absorption properties of the finished web **10**, **10'**, **10"** or **11**. This is an important attribute when the finished high loft, nonwoven web **10**, **10'**, **10"** or **11** is to be used for sound and/or thermal insulation purposes.

[0049] Still referring to FIG. **7**, one will notice that each of the first and second rotatable drums, **48** and **50** respectively, has a central axis **56** and **58**, respectively. Desirably, each of the central axes **56** and **58** are aligned on a common vertical plane, designated X_1-X_1. A horizontal distance measured from the distal end **42** of each nozzle **38** perpendicular to the vertical plane X_1-X_1 established a Die-to-Collector Distance (DCD). This DCD distance can range from between about 10 cm to about 150 cm. Desirably, the DCD distance is less than about 100 cm. More desirably, the DCD distance is less than about 90 cm. Even more desirably, the DCD distance is less than about 80 cm. Most desirably, the DCD distance is less than about 60 cm. The exact DCD distance is dependent upon a number of factors including but not limited to: the melt temperature of the polymer being extruded, the polymer throughput through the plurality of nozzles **38**, etc. However, it has been found through experimentation, that the closer the moving surfaces **44** and **46** are located from the distal end **42** of each of the plurality of nozzles **38**, the better the recovery value of the manufactured high loft, nonwoven web **10**, **10'**, **10"** or **11** is after compression. When the DCD distance ranges from between about 45 cm to about 75 cm, a high loft, nonwoven web **10**, **10'**, **10"** or **11** can be manufactured with a good recovery value after compression.

[0050] The outer peripheries of the first and second rotatable drums, **48** and **50** respectively, are spaced apart from one another thereby creating a convergence passage **60**. By "convergent passage" it is meant a point of converging, to approach a point. This converging passage **60** narrows down to a dimension equal to a nip **62** established between the first and second rotatable drums, **48** and **50** respectively. The nip **62** can vary in dimension. The first and second rotating drums, **48** and **50** respectively, should be mounted such that the dimension of the nip **62** established therebetween can be easily adjusted. Generally, the nip **62** can range from between about 0.5 cm to about 25 cm. Desirably, the nip **62** is greater than about 0.5 cm. More desirably, the nip **62** ranges from between about 0.5 cm to about 10 cm. Even more desirably, the nip **62** ranges from between about 0.5 cm to about 8 cm. Most desirably, the nip **62** is less than about 5 cm.

[0051] The convergent passage **60** has an entry **64** and an exit **66** established by the circumference of the first and second rotatable drums, **48** and **50** respectively. As the plurality of filaments **40** are deposited at the entry **64** of the convergent passage **60** they are directed and routed onto and between the pair of moving surfaces **44** and **46**. The routing is facilitated by the rotation of the first and second rotatable drums, **48** and **50** respectively. The routing causes the plurality of filaments **40** to pass through the convergent passage **60** in descending travel from the entry **64** to the exit **66**. The rotational movement of the first and second rotatable drums, **48** and **50** respectively, will cause some of the plurality of filaments **40** to temporarily contact the outer peripheries of the first and second rotatable drums, **48** and **50** respectively. These filaments **40** will be compressed against the remaining filaments **40** passing through the nip **62** to create a 3-dimensional structure **68**. The plurality of filaments **40** will be compressed at the nip **62** and this confined space helps the filaments **40**, which are transformed into fibers **12** as they cool, to be aligned in the x, y and z directions. By "transformed" it is meant to change markedly the appearance or form of; to change the nature, function, or condition of; convert. Thus a 3-dimensional structure **68** is produced instead of a 2-dimensional structure. The 3-dimensional structure **68** usually will not have a very good recovery value unless fiber-to-fiber bonds are created using some known bonding process to stabilize the formed 3-dimensional structure **68**.

[0052] Still referring to FIG. **7**, the 3-dimensional structure **68** is advanced in the machine direction (MD) in a horizontal direction. However, if the apparatus **34** is not horizontally oriented or if additional support is needed, a conveyor belt **70** can be utilized. The conveyor belt **70** can be constructed with a screen having a porous or open pattern to allow heat to pass therethrough freely. The conveyor belt **70** can move in a given direction over a plurality of rollers **72**. Four rollers **72** are depicted in FIG. **7**, although any number of rollers **72** can be utilized. One of the rollers **72** is the drive roller and the remaining rollers **72**, **72** and **72** are idler or follower rollers. The conveyor belt **70** makes a continuous loop and is illustrated moving in a clockwise direction so as to advance the 3-dimensional structure **68** in the downward machine direction (MD).

[0053] It should be understood that some high loft, nonwoven webs **10** can be formed from certain materials and for certain uses, wherein bonding is not necessary. However, for most high loft, nonwoven webs **10**, it is advantageous to subject the 3-dimensional structure **68** to a bonding process. Bonding generally imparts strength and integrity into the finished web **10**. Various bonding techniques can be utilized. A single bonder or a pair of oppositely aligned bonders can be utilized.

[0054] Still referring to FIG. **7**, a bonder **74** is shown located downstream of and in vertically alignment with the pair of moving surfaces **44** and **46** for bonding the 3-dimensional structure **68**. The bonder **74** is located such that the 3-dimensional structure **68** passes therethrough. The bonder **74** can be a thermal bonder, such as: a through air bonder or an oven bonder. A thermal bonder can function by creating heat. For example, the heat can be created by a heated fluid, such as gases or liquid, burning a solid, such as coal, heating inert gases, using steam, using secondary radiation from nanoparticles, using infra-red heat, etc. The bonder **74** itself can include a furnace, an oven, thermoelectric elements, etc., or any combination thereof. In addition, the bonder **74** can be a chemical bonder, a mechanical bonder, a hydro-mechanical bonder, needle bonder, a wet bonder, etc.

[0055] The heat from a thermal bonder will lock some of the fibers **12** to one another in the x, y and z directions. All the fibers **12** do not have to be bonded together, just enough to create the high loft, nonwoven web **10**. The fibers **12** are created as the plurality of filaments **40** solidify in the 3-dimensional structure **68**. By bonding some of the plurality of fibers **12** together, a high loft, nonwoven web **10** is create having a thickness of less than about 250 mm, desirably, less than about 200 mm, and more desirably, less than about 100 mm. The high loft, nonwoven web **10** also has a basis weight ranging from between about 50 g/m^2 to about 3,000 g/m^2, desirably, from between about 100 g/m^2 to about 2,000 g/m^2, and more desirably, from between about 100 g/m^2 to about 600 g/m^2. Furthermore, a vertical cross-section of the web **10**, when taken parallel to its machine direction, exhibits a plurality of snugly stacked, approximately V, U, or C-shaped structures **24**. Each of the approximately V, U or C-shaped structures **24** has an apex **26** facing in the machine direction, in other words, the approximately V or U shaped structure is rotated 90 degrees to a horizontal orientation with the apex of each facing to the right. The C-shaped structure is reversed in position so that the apex of each faces to the right. This high loft, nonwoven web **10** has a recovery value ranging from between about 20% to about 99% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes, according to IST 120.2 (01). The IST 120.2 (01) test requires the material to be compressed under a pressure of 0.25 psi for a time period of 30 minutes. Desirably, the high loft, nonwoven web **10** has a recovery value ranging from between about 30% to about 95% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes, according to IST 120.2 (01). More desirably, the high loft, nonwoven web **10** has a recovery value ranging from between about 40% to about 90% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes, according to IST 120.2 (01). Most desirably, the high loft, nonwoven web **10** has a recovery value ranging from between about 50% to about 80% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes, according to IST 120.2 (01).

[0056] Still referring to FIG. **7**, the apparatus **34** may further include one or more dispensing mechanisms **76** and **78** for adding chemical binders, or dispensing one or more additives **80** to the high loft, nonwoven web **10**. Two dispensing mechanisms **76** and **78** are illustrated in FIG. **7**. Chemical bonding system can be utilized instead of the thermal bonding systems. Chemical binders may impart some new features to the web such as different surface chemistry, more stiffness or roughness. The exact number of dispensing mechanisms can vary. Typically, one or two dispensing mechanisms **76** or **78** are utilized to add one or more additives to the high loft, nonwoven web **10**. The additive **80** can be any of those described above, as well as others known to those skilled in the art.

[0057] It should be understood that the high loft, nonwoven web **10** could also be partially or fully immersed in a liquid solution containing an additive **80**. The liquid solution could be chemically or electrically charged so as to cause the additive **80** to better adhere to the high loft, nonwoven web **10**.

[0058] Still referring to FIG. **7**, the apparatus **34** may also include a conditioning unit **82** situated downstream from the last dispensing mechanism **76** or **78**. The conditioning unit **82** can vary in design and function. The conditioning unit **82** could be a dryer that can remove moisture from the web **10** by utilizing heat or some other process when the high loft, nonwoven web **10** has to be dried. Alternatively, the conditioning unit **82** could be a cooler that could blow cool air onto the high loft, nonwoven web **10** and reduce its temperature. Still further, the conditioning unit **82** could perform some other function, for example embossing the web **10**, printing the web **10**, combining the high loft, nonwoven web **10** with another layer, etc. Dryers and coolers are appliances well known to those skilled in the art.

[0059] Referring now to FIG. **8**, another embodiment of an apparatus **34'** is depicted wherein the pair of moving surfaces **44** and **46** is shown as a first conveyor belt **52** and a second conveyor belt **54**. The orientation of the apparatus **34'** is vertical although other orientations could also be employed. The first conveyor belt **52** moves in a counterclockwise direction while the second conveyor belt **54** moves in a clockwise direction. This arrangement causes the plurality of filaments **40** emitted, ejected or extruded from the plurality of nozzles **38** to move vertically downward in a machine direction (MD). The first and second conveyor belts, **52** and **54** respectively, can run at various speeds. Desirably, the first and second conveyor belts, **52** and **54** respectively, will run at the same speed.

[0060] The first and second conveyor belts, **52** and **54** respectively, converge toward one another at a point located farthest away from the distal end **42** of each of said plurality of nozzles **38**. An opening **55**, equivalent to the nip **62**, is present between the first and second conveyor belts **52** and **54** respectively. The opening **55** occurs and is situated at a plane X_2-X_2. The plane X_2-X_2 is equivalent to the plane X_1-X_1, shown in FIG. **7**. A vertical distance measured from the distal end **42** of each nozzle **38** perpendicular to the plane X_2-X_2 established a Die-to-Collector Distance (DCD). This DCD distance can range from between about 10 cm to about 150 cm. Desirably, the DCD distance is less than about 100 cm. More desirably, the DCD distance is less than about 90 cm. Even more desirably, the DCD distance is less than about 80 cm. Most desirably, the DCD distance is less than about 60 cm. The exact DCD distance is dependent upon a number of factors including but not limited to: the melting temperature of the polymer being extruded, the basis weight of the material being produced, the polymer throughput through the plurality of nozzles **38**, and the inside diameter of each of the nozzles, etc.

[0061] As clearly shown in FIG. **8**, the first and second conveyor belts, **52** and **54** respectively, are aligned at an angle alpha (α) to one another. The angle α can vary. Desirably, the angle α is less than about 90 degrees. More desirably, the angle α is less than about 60 degrees. Even more desirably, the angle α is less than about 50 degrees. Most desirably, the angle α is less than about 45 degrees. An angle α of from between about 15 degrees to about 45 degrees works well. This orientation creates a convergent passage **60** and a nip **62**. The plurality of filaments **40** are deposited at the entry **64** of the convergent passage **60** as they are directed and routed onto and between the first and second conveyor belts, **52** and **54** respectively. The routing is facilitates by the movement of the first and second conveyor belts, **52** and **54** respectively. The routing causes the plurality of filaments **40** to pass through the convergent passage **60** in descending travel from the entry **64** to the exit **66**. The movement of the first and second conveyor belts, **52** and **54** respectively, will cause some of the plurality of filaments **40** to temporarily contact the outer peripheries of the first and second conveyor belts, **52** and **54** respectively. These filaments **40** will be compressed against the remaining filaments **40** passing through the nip **62** to create a 3-dimensional structure **68**. The plurality of filaments **40** will be compressed at the nip **62** and this confined space helps the filaments **40**, which are transformed into fibers **12** as they cool, to be aligned in the x, y and z directions. By "transformed" it is meant to change markedly the appearance or form of; to change the nature, function, or condition of; convert. Thus a 3-dimensional structure **68** is produced instead of a 2-dimensional structure. The 3-dimensional structure **68** usually will not have a very good recovery value unless fiber-to-fiber bonds are created using some known bonding process to stabilize the formed 3-dimensional structure **68**.

[0062] Still referring to FIG. **8**, the apparatus **34'** also differs from the apparatus **34**, shown in FIG. **7**, in that the 3-dimensional structure **68** is advanced in a vertical, downward direction until it contacts a conveyor belt **84**. The conveyor belt **84** is positioned perpendicular to the downward direction of the 3-dimensional structure **68**. The conveyor belt **84** moves through a continuous loop in a clockwise direction. The conveyor belt **84** causes the 3-dimensional structure **68** to make a 90 degree turn to the right. This new horizontal, rightward movement is referred to as machine direction (MD').

[0063] The conveyor belt **84** is mounted on a plurality of rollers **86**. Four rollers **86** are depicted in FIG. **8** although any number of rollers **86** can be utilized. One of the rollers **86** is the drive roller and the remaining rollers **86**, **86** and **86** are idler or follower rollers.

[0064] It should be understood that some high loft, nonwoven webs **10** can be formed from certain materials and for certain uses, wherein bonding is not necessary. However, it is advantageous when producing most nonwoven webs **10** to subject the 3-dimensional structure **68** to a bonding process. Bonding generally imparts strength and integrity into the finished web **10**. Various bonding techniques can be utilized. In FIG. **8**, a single bonder **74** is utilized. Upon exiting the bonder **74**, a high loft, nonwoven web **10** will be formed. The high loft, nonwoven web **10** has a thickness t.

[0065] Referring now to FIG. **9**, still another apparatus **34"** is shown which utilized a combination of a first meltblown die **88**, a spunbond die **90** and a second meltblown die **92**. The apparatus **34"** is shown being oriented in a vertical configuration, although other configurations are possible. The spunbond die **90** is positioned between the first and second meltblown dies, **88** and **92** respectively. This die arrangement produces a comingled, high loft hybrid nonwoven web that may have different fiber size, different polymeric materials, and/or different fiber cross-section.

[0066] It should be understood that various combinations can be obtained using one or more spunbond dies, meltblown dies, spunmelt dies, etc. When one wishes to manufacture a two layer web **10'**, as shown in FIG. **3**, two layers can be laminated inline or off-line. When one wishes to manufacture a three layer web **10'**, as shown in FIG. **4**, three systems similar to FIG. **7** can be utilized and the layers can be laminated inline or off-line with another ready-made web. Each die **88**, **90** and **92** will emit, eject, extrude, spin, or otherwise route a plurality of filaments **40** in a vertical, horizontal or outward direction. The remaining equipment is similar to that shown and explained with reference to FIG. **7**. One exception is that the Die-to-Collector Distance (DCD) is calculated by the distance from the middle spunbond die **90** to the plane X_1-X_1. Again, this DCD distance can range from between about 10 cm to about 150 cm. Desirably, the DCD distance is less than about 100 cm. More desirably, the DCD distance is less than about 90 cm. Even more desirably, the DCD distance is less than about 80 cm. Most desirably, the DCD distance is less than about 60 cm. The exact DCD distance is dependent upon a number of factors including but not limited to: the melt temperature of the polymer being extruded, the polymer throughput through the plurality of nozzles **38**, etc. However, it has been found through experimentation, that the closer the moving surfaces **44** and **46** are located from the distal end **42** of each of the plurality of nozzles **38**, the better the recovery value of the manufactured high loft, nonwoven web **10**, **10'**, **10"** or **11** is after compression. When the DCD distance ranges from between about 45 cm to about 75 cm, a high loft, nonwoven web **10**, **10'**, **10"** or **11** can be manufactured with a good recovery value after compression.

[0067] A 3-dimensional structure **68** emerges from the exit **66** of the convergent passage **60**. As explained above, it may be advantageous to bond the fibers **12** of the 3-dimensional web **10"** together to increase the strength and improve the integrity of the web **10"**. A bonder **74** is positioned downstream of the first and second rotatable drums **48** and **50** respectively. The bonder **74** can be any of the various kinds of bonders explained above. Desirably, the bonder **74** is a thermal or chemical bonder.

[0068] It should be understood that in any of the three apparatuses **34**, **34'** or **34"** described above, that one could add one or more features to them. For example, one could introduce natural or synthetic man-made fibers into the high loft, nonwoven web **10**, **10'**, **10"** or **11** during the manufacturing process. Likewise, non-thermoplastic materials could also be added to the webs **10**, **10'**, **10"** or **11** during manufacture.

[0069] Furthermore, one could spin or extrude multi-component fibers, fibers having different cross-sectional diameters, use curly fibers within the webs **10**, **10'**, **10'** or **11**, or otherwise treat the fibers **12** is a particular way to obtain a unique finished high loft, nonwoven web **10**, **10"**, **10"** or **11**.

[0070] It should also be recognized that the various processes, such as meltblown, spunbond, spunmelt, etc. may require that the filaments be attenuated at different temperatures, pressures, flow rates, etc. For example, the process air could be colder or hotter than the polymer melt.

Process

[0071] The process of forming the high loft, nonwoven web **10**, **10'**, **10"** or **11** will be explains with reference to FIGS. **7-9**. The process includes introducing a molten polymer to a die **36**. The die **36** has a plurality of nozzles **38** each having a distal end **42**. The molten polymer is emitted through the plurality of nozzles **38** to form a plurality of filaments **40**. By "emitting" it is meant extruding, ejecting, spinning, forcing or discharging the molten polymer under pressure, in any of the known processes described above and/or known to those skilled in the art. The process also includes using air or gas streams to facilitate movement and drawing of the plurality of filaments **30**. The filaments **40** are directed towards a pair of moving surfaces **44** and **46**, located at a distance of from between about 10 cm to about 150 cm from the plurality of nozzles **38**. The pair of moving surfaces **44** and **46** can be first and second rotatable drums, **48** and **50** respectively, or can be first and second conveyor belts, **52** and **54** respectively.

[0072] The pair of moving surfaces **44** and **46** forms a convergent passage **60** having an entry **64** and an exit **66**. The plurality of filaments **40** are deposited into the entry **64** of the convergent passage **60**. The plurality of filaments **40** are then routed through the convergent passage **60** in descending travel from the entry **64** to the exit **66** and between the pair of moving surfaces **44** and **46** in a machine direction to form a 3-dimensional structure **68**. In the 3-dimensional structure **68**, the filaments **40** are transformed upon cooling into fibers **12** oriented in the x, y and z directions. The process further includes bonding the 3-dimensional structure **68** to form a high loft, nonwoven web **10**, **10'**, **10"** or **11** having a thickness t, t or t_2 of less than about 250 millimeters and a basis weight ranging from between about 50 g/m^2 to about 3,000 g/m^2. The 3-dimensional structure **68** can be bonded using a variety of different bonders. Some bonders which can be used include but are not limited to: thermal bonding, through air bonding, oven bonding, chemical bonding, wet bonding, mechanical bonding or hydro-mechanical bonding.

[0073] A vertical cross-section of the high loft, nonwoven web **10**, **10'**, **10"** or **11**, when taken parallel to the machine direction (MD), exhibits a plurality of snugly stacked, approximately V, U or C-shaped structures **24**. Each of the approximately V, U or C-shaped structure **24** has an apex **26** facing in the machine direction (MD), in other words, the approximately V or U shaped structure is rotated 90 degrees to a horizontal orientation with the apex of each facing to the right. The C-shaped structure is reversed in position so that the apex of each faces to the right. The high loft, nonwoven web **10**, **10'**, **10"** or **11** has a recovery value ranging from between about 20% to about 99% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes.

[0074] Referring again to FIGS. **3**, **4** and **9**, it is possible to utilize two separate and distinct dies **36** and **36** to produce a two layered web **10'**, see FIG. **3**. One could also utilize three separate and distinct dies **36**, **36** and **36** to produce a three layered web **10"**, see FIG. **4**. Likewise, one could utilize four or more separate and distinct dies, **36**, **36**, **36** and **36** to produce a multi-layered web having 4 or more layers. Structure in these hybrid nonwoven high loft materials of the comingled fibers or the laminated layers may have different fiber size, different polymeric materials, and/or different fiber cross-section.

[0075] It should be understood that an additive **80** can be added to the high loft, nonwoven web **10**, **10'**, **10"** or **11** downstream of the bonder **74**. The additive **80** can be any of those mentioned above. The additive **80** can be deposited onto the high loft, nonwoven web **10**, **10'**, **10"** or **11**, or it could be sprayed thereon. Alternatively, the high loft, nonwoven web **10**, **10'**, **10"** or **11** could be immersed in a liquid solution containing an additive **80**.

[0076] It should also be understood that the high loft, nonwoven web **10**, **10'**, **10"** or **11** can be dried downstream of the bonder **74**. Likewise, the high loft, nonwoven web **10**, **10'**, **10"** or **11** could be cooled downstream of the bonder **74**. Such cooling could reduce the temperature of the high loft, nonwoven web **10**, **10'**, **10"** or **11** to room temperature or thereabout.

EXPERIMENTS

1. Meltblowing Unit

[0077] A number of high loft, nonwovens sample webs were produced using a meltblowing pilot line that had a 381 mm meltblowing die with multi-row spinnerettes known as the Biax meltblowing (MB) die. This die is commercially available from Biax-Fiberfilm Corporation having an office at

N992 Quality Drive, Suite B, Greenville, Wis. 54942. The meltblowing spinnerettes had 242 polymer nozzles. The inside diameter of each spinnerette was 0.508 millimeters (mm) while the outside diameter of each spinnerette was 0.711 mm. Each polymer nozzle was surrounded by an air nozzle where the blowing air was coming from the annular space between the polymer nozzle and the air nozzle. The diameter of each of the air nozzles was 1.4 mm. The Biax meltblowing (MB) die design is taught in U.S. Pat. No. 5,476,616 and U.S. Patent Publication 2005/0056956 A1. Typical commercial Biax meltblowing (MB) dies have from between about 6,000 to about 11,000 nozzles per meter.

2. Process Conditions

[0078] Several examples of high loft, nonwoven webs were made using the pilot meltblowing line to prove the concept of this invention. It should be understood that the high loft, nonwoven webs could also have been made using spunbond equipment. Furthermore, it should be understood that the exact process conditions used to make these samples could be changed. Any variation of the process conditions, such as air temperature, polymer chemistry or type, polymer melt temperature, polymer throughput, air throughput, etc. could be changed.

[0079] The first seven (7) nonwoven web samples were made of polypropylene that was provided by Exxon-Mobil under the trade name: ACHIEVE 6936G1. This polypropylene had a typical melt flow rate of 1,550 grams per 10 minutes (according to ASTM test D 1238, 230° C., 2.16 kg). The last two (2) nonwoven web samples (samples 8 and 9) were made of polylactic acid that was provided by Natureworks under the trade name: INGEO PLA 6202D. The polylactic acid had a melt flow rate of 15 grams (g) to 30 g per 10 minutes (according to ASTM test D 1238, 210° C., 2.16 kg).

[0080] Polypropylene samples were fabricated at the following process conditions:

[0081] Polymer melt temperature: 190° C.

[0082] Air temperature: 170° C.

[0083] Polymer throughput: 0.26 g/hole/minute

[0084] Air pressure: 35 KPa

[0085] The basis weight of these samples varied from between about 150 g/m^2 to 500 g/m^2 by varying the speed of the first and second rotatable drums or by varying the speed of the first and second conveyor belts. The Die to Collector Distance (DCD) varied between about 30 centimeters (cm) to about 45 cm.

[0086] Polylactic acid samples were made at the following process conditions;

[0087] Polymer melt temperature: 260° C.

[0088] Air temperature: 260° C.

[0089] Polymer throughput: 1 g/hole/minute

[0090] Air pressure: 35 KPa

[0091] The basis weight was around 500 g/m^2 and the Die-to-Collector Distance (DCD) was around 75 cm.

[0092] Some of the samples were thermally bonded using an infra-red oven at a temperature of 120° C. and the dwell time (contact time) was about 3 seconds to about 5 seconds.

3. Characterization Tests

3.1 Basis Weight

[0093] Basis weight is defined as the mass per unit area and it can be measured in grams per meter squared (g/m^2). The basis weight test is done according the INDA standard IST 130.1 which is equivalent to the ASTM standard ASTM D3776. Ten (10) different samples were die cut from different locations in a larger sample web and each one had an individual area equal to 100 cm^2. The weight of each replicate was measured using a sensitive balance within ±0.1% of weight on the balance. The basis weight in grams/m^2 was measured by multiplying the average weight by 100.

3.2 Thickness of the High Loft Nonwoven

[0094] Thickness is defined as the distance between one surface and an opposite surface of a single web measured under a specified pressure. For high loft, nonwoven webs, the thickness was measured according the INDA standard IST 120.2 (01). The apparatus include a thickness testing instrument that had: an anvil, a presser foot, and a scale indicating the distance between these two parallel plates. The foot presser was 305 mm×305 mm (12 inches×12 inches) in size and had a weight of 288 grams. Five representative specimens of the fabric were die cut and tested in the standard atmosphere for testing as prescribed in ASTM D1776. Samples were handled carefully to avoid altering the natural state of the fabric. Each specimen was placed on the bottom plate and the presser foot was placed with care on the top of the sample. The average thickness of these specimens is reported along with a standard deviation.

3.3 Compression and Recovery of the High Loft Nonwovens

[0095] In this test, one measures the compression and recovery performance of the high loft, nonwoven web samples by observing the linear distance that a movable plane is displaced from a parallel surface by the high loft, nonwoven web samples while under a specified pressure. After a specified time interval, the pressure is removed and the recovery of the linear distance is measured. The performance of the high loft, nonwoven webs for use in furniture, clothing, and insulation applications (acoustic or thermal) may be estimated from these compression and recovery values. The original thickness T**1**, measured in millimeters (mm), was measured according to the IST 120.2 (01). The presser foot was raised and the 288 gram weight was replaced with 16.33 Kg (36 pounds) to provide a pressure of 1720 Pa (0.25 psi). The presser foot with the new weight was placed on top of the high loft, nonwoven webs samples for 30 minutes and then the compressed thickness T**2** was measured. Finally, the presser foot was raised and replaced by the 36 pound weight with the 288 gram weight. After five (5) minutes, the presser foot was lowered to measure the thickness recovered, T**3**.

$$\text{Percent compression}=[(T1-T2)/T1]\times 100$$

$$\text{Percent Recovery}=[T3/T1]\times 100$$

Example 1

[0096] In this example, the effects of the collector type on the high loft, nonwoven web properties were looked at. Sample 1 and 2 showed a big difference in thickness or caliper of the nonwoven web. The big difference is mainly due to collecting the spun fibers on a flat belt versus collecting them between two rotating drums having a nip gap of 2.5 cm. The dual drum collection system increased the thickness by 1,500% although both samples have the same mass per unit area. Sample 3 showed that by thermally bonding the high loft, nonwoven sample #2, one could enhance the recovery properties by 26%. Such enhancement will greatly increase the thermal insulation and acoustical properties of a web. With the proper tuning of the fiber formation conditions and the bonding conditions, the compression and recovery properties can be greatly enhanced, see Table 1 below.

TABLE 1

Table (1): Effect of Collector type on polypropylene high loft nonwoven samples

Sample	DCD, (cm)	Collector type	Nip gap, (cm)	Bonding	Basis weight, (g/m^2)	Thickness, (mm)	Percent compression (%)	Percent Recovery (%)
# 1	45	flat belt	NA	No	150.7	0.81	NA	NA
# 2	45	dual drum	2.5	No	147.8	13.6	72	53.6
# 3	45	dual drum	2.5	Thermally Bonded	142.6	12.6	72.4	67.7

Example 2

[0097] In this example, the effect of the Die-to-Collector Distance (DCD) on the compression-recovery properties of the high loft nonwoven web samples were looked at. The meltblown filaments were collected at a distance close to the die, where they are very tacky. This action created fiber to fiber bonding in the high loft, nonwoven web samples between the first and second rotatable drums and avoided the need for additional downstream bonding. This might work on equipment operating at a low polymer throughput to produce a high loft, nonwoven web with a basis weight of less than about 150 g/m^2. However, when the polymer throughput and the basis weight increases, the blowing air causes the filaments to fly around and they prevent being captured on the first and second rotatable drums because of the difficult air management at a closer Die-to-Collector Distance (DCD). Samples 2 and 3 were collector at a DCD distance of 45 cm from the die face. Samples 4 and 5 were collected at a DCD distance of 30 cm from the die face. As shown in Table 2, collecting the fibers at a closer DCD distance, as in sample 4, enhanced the fiber to fiber bonding and achieved similar recovery performance to sample 3, which was thermally bonded. Sample 5 was obtained by oven bonding sample #4. However, it was found that this additional bonding actually decreased the recovery properties of sample 5 by 28% because the additional bonding actually caused the fibers to become brittle.

TABLE 2

Table (2): Effect of Die-to-collector distance on polypropylene high loft nonwovens

Sample	DCD, (cm)	Collector type	Nip gap, (cm)	Bonding	Basis weight, (g/m^2)	Thickness, (mm)	Percent Compression (%)	Percent Recovery (%)
# 2	45	dual drum	2.5	No	147.8	13.6	72.3	53.6
# 3	45	dual drum	2.5	Thermally Bonded	142.6	12.6	72.4	67.7
# 4	30	dual drum	2.5	No	146.5	13.5	73.3	65.6
# 5	30	dual drum	2.5	Thermally Bonded	151.25	19.8	81.7	47.7

Example 3

[0098] In this example, the effect that basis weight had on the compression-recovery properties of the high loft, nonwoven web samples were looked at. As shown in Table 3, by increasing the mass per unit area, the compressibility decreased which is obvious because of the larger nonwoven mass passing between the nip of the first and second rotatable drums. It was also noticed that by increasing the basis weight, the percent recovery after compression also increased, which may be due to the larger number of fiber-to-fiber bonds that were created. Collecting the fibers of samples 6 and 7 at a closer Die-to-Collector Distance (DCD) was not successful on the pilot scale because of the difficult air management and the larger mass of filaments that blocked the way in front the blowing attenuation air.

TABLE 3

Table (3): Effect of Basis Weight on polypropylene high loft nonwovens

Sample	DCD, (cm)	Collector type	Nip gap, (cm)	Bonding	Basis weight, (g/m^2)	Thickness, (mm)	Percent compression (%)	Percent Recovery (%)
# 3	45	dual drum	2.5	Through Bonded	142.6	12.6	72.4	67.7
# 6	45	dual drum	2.5	Through Bonded	302.3	17.8	66.9	75.9
# 7	45	dual drum	2.5	Through Bonded	492.6	23.2	61.7	80.8

Example 4

[0099] In this example, the concept of collecting spunmelt fibers at the nip formed between two rotating drums, for different polymers, were looked at. Sample 8 and 9 were produced using polylactic acid resin. Despite the spinning difficulty of such polymer and the shrinkage effect that accompanied the web formation, two high loft, nonwoven samples were collected. As shown in Table 4, sample 8, which was not thermally bonded, had higher compressibility but lower recovery properties than sample 9 which was thermally bonded using the infra-red thermal oven. Sample 9 was also stronger than sample 8 during handling and had a better structure integrity as sample 9 was not falling apart because of the fiber-to-fiber bonds that were created during the post heat treatment. It is well known that structural integrity of the loose fibers can be enhanced by using other bonding techniques, such as through air bonding or chemical bonding.

TABLE 4

Table (4): PLA high loft nonwovens

Sample	DCD, (cm)	Collector type	Nip gap, (cm)	Bonding	Basis weight, (g/m^2)	Thickness, (mm)	Percent compression (%)	Percent Recovery (%)
# 8	75	dual drum	2.5	No	530	20.5	44.7	80.2
# 9	75	dual drum	2.5	Through Bonded	533	19.1	33.5	85.7

[0100] While the invention has been described in conjunction with several specific embodiments, it is to be understood that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, this invention is intended to embrace all such alternatives, modifications and variations which fall within the spirit and scope of the appended claims.

We claim:

1. A high loft, nonwoven web comprising a three dimensional structure with fibers oriented in the x, y and z directions, said web having a thickness of less than about 250 millimeters and a basis weight ranging from between about 50 g/m^2 to about 3,000 g/m^2, and a vertical cross-section of said web, when taken parallel to a machine direction, exhibiting a plurality of snugly stacked, approximately V, U or C-shaped structures, with each V, U or C-shaped structure having an apex facing in said machine direction, and said web having a recovery value ranging from between about 20% to about 99% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes.

2. The high loft, nonwoven web of claim **1** wherein said web has a density ranging from between about 10 Kg/m^3 to about 250 Kg/m^3.

3. The high loft, nonwoven web of claim **1** wherein said web is thermally bonded.

4. The high loft, nonwoven web of claim **1** wherein said web is chemically bonded.

5. The high loft, nonwoven web of claim **1** wherein said web is formed from polyolefin.

6. The high loft, nonwoven web of claim **1** wherein said web is formed from polypropylene having a melt flow rate ranging from between about 4 g/10 min. to about 6,000 g/10 min at a temperature of 230° C. and at a pressure of 2.16 kg.

7. The high loft, nonwoven web of claim **1** wherein said web contains an additive.

8. The high loft, nonwoven web of claim **7** wherein said additive is selected from the group consisting of: a superabsorbent, absorbent particles, polymers, nanoparticles, abrasive particulars, active particles, active compounds, ion exchange resins, zeolites, softening agents, plasticizers, ceramic particles pigments, dyes, flavorants, aromas, controlled release vesicles, binders, adhesives, tackifiers, surface modification agents, lubricating agents, emulsifiers, vitamins, peroxides, antimicrobials, deodorizers, fire retardants, flame retardants, antifoaming agents, anti-static agents, biocides, antifungals, degradation agents, stabilizing agents, conductivity modifying agents, or any combination thereof.

9. The high loft, nonwoven web of claim **1** wherein said web contains at least two separate and distinct layers, and said web has two major surfaces and at least one of these major surfaces is textured.

10. A high loft, nonwoven web comprising at least two layers each having a three dimensional structure with fibers oriented in the x, y and z directions, said web having a thickness of less than about 200 millimeters and a basis weight of from between about 50 g/m^2 to about 2,000 g/m^2, said web being through air bonded, and a vertical cross-section of each layer of said web, when taken parallel to a machine direction, exhibiting a plurality of snugly stacked, approximately V, U or C-shaped structures, with each V, U or C-shaped structure having an apex facing in said machine direction, and said web having a recovery value ranging from between about 30% to about 95% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes.

11. The high loft, nonwoven web of claim **10** wherein said web is formed from a polymer selected from the group consisting of: polyolefins, polyesters, polyethylene terephthalates, polybutylene terephthalates, polycyclohexylene dimethylene terephthalates, polytrimethylene terephthalates, polymethyl methacrylates, polyamides, nylons, polyacrylics, polystyrenes, polyvinyls, polytetrafluoroethylenes, ultrahigh molecular weight polyethylenes, very high molecular weight polyethylenes, high molecular weight polyethylenes, polyether ether ketones, non-fibrous plasticized celluloses, polyethylenes, polypropylenes, polybutylenes, polymethylpentenes, low-density polyethylenes, linear low-density polyethylenes, high-density polyethylenes, polystyrenes, acrylonitrile-butadiene-styrenes, styrene-acrylonitriles, styrene-butadienes, styrene-maleic anhydrides, ethylene vinyl acetates, ethylene vinyl alcohols, polyvinyl chlorides, cellulose acetates, cellulose acetate butyrates, plasticized cellulosics, cellulose propionates, ethyl celluloses, natural fibers, any derivative thereof, any polymer blend thereof, any copolymer thereof or any combination thereof.

12. The high loft, nonwoven web of claim **10** wherein said web has two major surfaces and at least one of these major surfaces is textured.

13. The high loft, nonwoven web of claim **10** wherein said web has two major surfaces and both of these major surfaces is textured.

14. The high loft, nonwoven web of claim **10** wherein said additive is selected from the group consisting of: a superabsorbent, absorbent particles, polymers, nanoparticles, abrasive particulars, active particles, active compounds, ion exchange resins, zeolites, softening agents, plasticizers, ceramic particles pigments, dyes, flavorants, aromas, controlled release vesicles, binders, adhesives, tackifiers, surface modification agents, lubricating agents, emulsifiers, vitamins, peroxides, antimicrobials, deodorizers, fire retardants, flame retardants, antifoaming agents, anti-static agents, biocides, antifungals, degradation agents, stabilizing agents, conductivity modifying agents, or any combination thereof.

15. A high loft, nonwoven web comprising at least two layers of fibers, each layer emitted from a different spinning head with a plurality of nozzles, said fibers being deposited on a forming wire to form a three dimensional structure with fibers oriented in the x, y and z directions, said web having a thickness of less than about 100 millimeters and a basis weight of from between about 50 g/m^2 to about 1,000 g/m^2, said web being bonded, and a vertical cross-section of said web, when taken parallel to a machine direction, exhibiting a plurality of snugly stacked, approximately V, U or C-shaped structures, with each V, U or C-shaped structure having an apex facing in said machine direction, and said web having a recovery value ranging from between about 40% to about 90% after being compressed under a pressure of 0.25 psi for a time period of 30 minutes.

16. The high loft, nonwoven web of claim **15** wherein said web is thermally bonded.

17. The high loft, nonwoven web of claim **15** wherein said web is chemically bonded.

18. The high loft, nonwoven web of claim **15** wherein said web has two major surfaces and both of these major surfaces is textured.

19. The high loft, nonwoven web of claim **15** wherein said web is formed from a polymer which is selected from the group consisting of: polyolefins, polyesters, polyethylene terephthalates, polybutylene terephthalates, polycyclohexylene dimethylene terephthalates, polytrimethylene terephthalates, polymethyl methacrylates, polyamides, nylons, polyacrylics, polystyrenes, polyvinyls, polytetrafluoroethylenes, ultrahigh molecular weight polyethylenes, very high molecular weight polyethylenes, high molecular weight polyethylenes, polyether ether ketones, non-fibrous plasticized celluloses, polyethylenes, polypropylenes, polybutylenes, polymethylpentenes, low-density polyethylenes, linear low-density polyethylenes, high-density polyethylenes, polystyrenes, acrylonitrile-butadiene-styrenes, styrene-acrylonitriles, styrene-butadienes, styrene-maleic anhydrides, ethylene vinyl acetates, ethylene vinyl alcohols, polyvinyl chlorides, cellulose acetates, cellulose acetate butyrates, plasticized cellulosics, cellulose propionates, ethyl celluloses, natural fibers, any derivative thereof, any polymer blend thereof, any copolymer thereof or any combination thereof.

20. The high loft, nonwoven web of claim **10** wherein said web contains one or more additive selected from the group consisting of: a superabsorbent, absorbent particles, polymers, nanoparticles, abrasive particulars, active particles, active compounds, ion exchange resins, zeolites, softening agents, plasticizers, ceramic particles pigments, dyes, flavorants, aromas, controlled release vesicles, binders, adhesives, tackifiers, surface modification agents, lubricating agents, emulsifiers, vitamins, peroxides, antimicrobials, deodorizers, fire retardants, flame retardants, antifoaming agents, antistatics agents, biocides, antifungals, degradation agents, stabilizing agents, conductivity modifying agents, or any combination thereof.

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