Disclosed herein is an apparatus for forming sheath-and-core fibers, the apparatus comprising a series of stacked distribution plates comprising channels arranged to convey first and second fluidized polymers separately and comprising a restriction zone for distributing the second fluidized polymer around the first polymer as a sheath. Also disclosed is a method for forming such sheath-and-core fibers. The apparatus and method are well suited to forming sheath-and-core fibers having very low percentage of sheath component.
APPARATUS AND METHOD FOR MULTICOMPONENT FIBERS

FIELD

[0001] The present invention is related to multicomponent fibers and particularly to sheath-and-core fiber multicomponent fibers.

BACKGROUND OF THE INVENTION

[0002] Many of the medical care garments and products, protective wear garments, mortuary and veterinary products, and personal care products in use today are partially or wholly constructed of extruded filamentary or fibrous web materials such as nonwoven web materials. Examples of such products include, but are not limited to, medical and health care products such as surgical drapes, gowns and bandages, protective workwear garments such as coveralls and lab coats, and infant, child and adult personal care absorbent articles such as diapers, training pants, disposable swimwear, incontinence garments and pads, sanitary napkins, wipes and the like. Other uses for nonwoven web materials include geotextiles and house wrap materials. For these applications nonwoven web materials provide functional, tactile, comfort and/or aesthetic properties that can approach or even exceed those of traditional woven textiles or knitted cloth materials.

[0003] The composition of the fibers in a fabric such as a nonwoven web has a significant impact on the functional, tactile, comfort and/or aesthetic properties of the fabric or material. As an example, the fibers of nonwoven webs are often made of or include one or more thermoplastic polymers having different physical properties that can affect the properties of the web material, and for certain applications it is highly desirable to have polymers of more than one type incorporated into a single fiber as a multicomponent or conjugate fiber. There is a continuing need for efficient and controllable fiber extrusion apparatus and methods which offer the ability to produce multicomponent fibers.

SUMMARY OF THE INVENTION

[0004] The present invention provides an apparatus and method for the production of extruded multicomponent fibers. The apparatus comprises a series of stacked distribution plates, the distribution plates including channels arranged to conduct a first fluid along at least one vertical flow path and channels arranged to conduct a second fluid along first and second lateral flow paths, then along vertical paths, then along a second plurality of lateral paths, then along a second plurality of vertical paths, where the second plurality of vertical paths terminate in an annular-shaped lateral channel, the apparatus further including a restriction zone arranged between two of the distribution plates for receiving the second fluid from the annular-shaped lateral channel, and a spin plate having at least one extrusion capillary arranged to receive the first fluid and the second fluid. The apparatus is well suited to producing sheath-and-core fibers having a substantially continuous sheet area around the core and, in embodiments, where the sheet cross-sectional area is less than about 25 percent of the entire fiber cross-sectional area, and in further embodiments the sheet cross-sectional area is less than about 20 percent of the entire fiber cross-sectional area, or even less than about 15 percent, or even about 10 percent, or less, of the entire fiber cross-sectional area.

[0005] In another embodiment, the apparatus includes at least one extrusion capillary, a first distribution plate configured to conduct a first polymer along a vertical central path, and configured to conduct a second polymer along first and second lateral paths, then along a plurality of vertical paths, then along a plurality of lateral paths; a second distribution plate configured to conduct the first polymer along a vertical path, and configured to conduct the second polymer along a plurality of vertical paths, then along a plurality of lateral paths, the lateral paths forming an annular path, and the second distribution plate forming the upper portion of a restriction zone; and a third distribution plate forming the lower portion of the restriction zone and the third distribution plate configured to conduct the first and second polymers to the extrusion capillary.

[0006] The method comprises the steps of providing a plurality of stacked distribution plates and a spin plate including a plurality of extrusion capillaries; providing a first fluidized polymer and a second fluidized polymer; conveying the first polymer along a first vertical path through the stacked distribution plates to the extrusion capillary; conveying the second polymer along second paths through the stacked distribution plates, the second paths terminating in an annular-shaped lateral channel; conveying the second polymer through a restriction zone between the annular-shaped lateral channel and the first vertical path to envelop the first polymer with the second polymer; and extruding the first polymer and the second polymer from the extrusion capillary. In embodiments, the first fluidized polymer and the second fluidized polymer may be molten thermoplastic polymers. In other embodiments, one or more of the fluidized polymers may be an elastomeric polymer. Also provided are sheath-and-core fibers produced in accordance with embodiments of the method and nonwoven webs comprising the fibers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIGS. 1-3 illustrate schematically cross sections of the component configuration in sheath-and-core fibers.

[0008] FIGS. 4-6 illustrate schematically views of a portion of the apparatus of the invention.

[0009] FIGS. 7-9 illustrate schematically views of another portion of the apparatus of the invention.

[0010] FIGS. 10-11 illustrate schematically views of another portion of the apparatus of the invention. FIG. 12 illustrates schematically an alternate embodiment of the portion of the apparatus illustrated in FIGS. 10-11.

DEFINITIONS

[0011] As used herein and in the claims, the term “comprising” is inclusive or open-ended and does not exclude additional unrecited elements, compositional components, or method steps. Accordingly, the term “comprising” encompasses the more restrictive terms “consisting essentially of” and “consisting of”.

[0012] As used herein the term “polymer” generally includes but is not limited to, homopolymers, copolymers, such as for example, block, graft, random and alternating copolymers, terpolymers, etc. and blends and modifications thereof. Furthermore, unless otherwise specifically limited, the term “polymer” shall include all possible geometrical
configurations of the material. These configurations include, but are not limited to isotactic, syndiotactic and random symmetries. As used herein the term “thermoplastic” or “thermoplastic polymer” refers to polymers that will soften and flow or melt when heat and/or pressure are applied, the changes being reversible.

As used herein the term “fibers” refers to both staple length fibers and substantially continuous filaments, unless otherwise indicated. As used herein the term “substantially continuous” with respect to a filament or fiber means a filament or fiber having a length much greater than its diameter, for example having a length to diameter ratio in excess of about 15,000 to 1, and desirably in excess of 50,000 to 1.

As used herein the term “monocomponent” filament refers to a filament or fiber formed from one or more extruders using only one polymer. This is not meant to exclude filaments formed from one polymer to which small amounts of additives have been added for color, anti-static properties, lubrication, hydrophilicity, etc.

As used herein the term “multicomponent fibers” refers to fibers that have been formed from at least two component polymers, or the same polymer with different properties or additives, extruded from separate extruders but spun together to form one filament. Multicomponent fibers are also sometimes referred to as conjugate fibers or bicomponent fibers, although more than two components may be used. The polymers are arranged in substantially constantly positioned distinct zones across the cross-section of the multicomponent fibers and extend continuously along the length of the multicomponent fibers. The configuration of such a multicomponent fiber may be, for example, a concentric or eccentric sheath/core arrangement wherein one polymer is surrounded by another, or may be a side by side arrangement, an “islands-in-the-sea” arrangement, or arranged as pie-wedge shapes or as stripes on a round, oval or rectangular cross-section fiber, or other. Multicomponent fibers are taught in U.S. Pat. No. 5,108,820 to Kaneko et al., U.S. Pat. No. 5,336,552 to Strack et al., and U.S. Pat. No. 5,382,400 to Pike et al. For two component fibers, the polymers may be present in ratios of 75/25, 50/50, 25/75 or any other desired ratios. In any, given component of a multicomponent fiber may desirably comprise two or more polymers as a multiconstituent blend component.

As used herein the term “bicentric fiber” or “multiconstituent fiber” refers to a filament or fiber formed from at least two polymers, or the same polymer with different properties or additives, extruded from the same extruder as a blend. Multiconstituent fibers do not have the polymer components arranged in substantially constantly positioned distinct zones across the cross-section of the multicomponent fibers; the polymer components may form fibrils or protofibrils that start and end at random.

As used herein the term “nonwoven web” or “nonwoven fabric” means a web having a structure of individual fibers or fibers that are interlaid, but not in an identifiable manner as in a knitted or woven fabric. Nonwoven fabrics or webs have been formed from many processes such as for example, meltblowing processes, spunbonding processes, airlaying processes, and carded web processes. The basis weight of nonwoven fabrics is usually expressed in grams per square meter (gsm) or ounces of material per square yard (osy) and the fiber diameters useful are usually expressed in microns. (Note that to convert from osy to gsm, multiply osy by 33.91).

The term “spunbond” or “spunbond nonwoven web” refers to a nonwoven fiber or filament material of small diameter fibers that are formed by extruding molten thermoplastic polymer as fibers from a plurality of capillaries of a spinneret. The extruded fibers are cooled while being drawn by an eductive or other well known drawing mechanism. The drawn fibers are deposited or laid onto a forming surface in a generally random manner to form a loosely entangled fiber web, and then the laid fiber web is subjected to a bonding process to impart physical integrity and dimensional stability. The production of spunbond fabrics is disclosed, for example, in U.S. Pat. Nos. 4,340,563 to Apell et al., 6,926,618 to Dorschner et al., and 5,802,817 to Matsuki et al. Typically, spunbond fibers or filaments have a weight-per-unit-length in excess of about 1 denier and up to about 6 denier or higher, although both finer and heavier spunbond fibers can be produced. In terms of fiber diameter, spunbond fibers often have an average diameter of larger than 7 microns, and more particularly between about 10 and about 25 microns, and up to about 30 microns or more.

As used herein the term “meltblown fibers” means fibers or microfibers formed by extruding a molten thermoplastic material through a plurality of fine, usually circular, die capillaries as molten threads or filaments or fibers into converging high velocity gas (e.g. air) streams that attenuate the fibers of molten thermoplastic material to reduce their diameter. Thereafter, the meltblown fibers are carried by the high velocity gas stream and are deposited on a collecting surface to form a web of randomly dispersed meltblown fibers. Such a process is disclosed, for example, in U.S. Pat. No. 3,849,241 to Buntin. Meltblown fibers may be continuous or discontinuous, are often smaller than 10 microns in average diameter and are frequently smaller than 7 or even 5 microns in average diameter, and are generally tacky when deposited onto a collecting surface.

As used herein, “thermal point bonding” involves passing a fabric or web of fibers or other sheet layer material to be bonded between a heated calender roll and an anvil roll. The calender roll is usually, though not always, patterned in some way so that the entire fabric is not bonded across its entire surface. As a result, various patterns for calender rolls have been developed for functional as well as aesthetic reasons. One example of a pattern has points and is the Hansen Pennings or “H&P” pattern with about a 30% bond area with about 200 bonds/square inch as taught in U.S. Pat. No. 3,855,046 to Hansen and Pennings. The H&P pattern has square point or pin bonding areas wherein each pin has a side dimension of 0.038 inches (0.965 mm), a spacing of 0.070 inches (1.778 mm) between pins, and a depth of bonding of 0.023 inches (0.584 mm). The resulting pattern has a bonded area of about 29.5%. Another typical point bonding pattern is the expanded Hansen and Pennings or “EHP” bond pattern which produces a 15% bond area with a square pin having a side dimension of 0.037 inches (0.94 mm), a pin spacing of 0.007 inches (2.464 mm) and a depth of 0.039 inches (0.991 mm). Other common patterns include a “Ramishl” diamond pattern with repeating diamonds having a bond area of about 8% to about 14% and 52 bonds/square inch and a wire weave pattern looking as the name suggests, e.g. like a window screen. Typically, the
percent bonding area varies from around 10% to around 30% of the area of the fabric laminate web. Thermal point bonding imparts integrity to individual layers by bonding fibers within the layer and/or for laminates of multiple layers, point bonding holds the layers together to form a cohesive laminate.

DETAILED DESCRIPTION OF THE INVENTION

[0021] The present invention provides an apparatus and method for making multicomponent fibers which may be used, for example, in fibrous fabrics and materials such as in nonwoven webs. The invention will be described with reference to the following Figures which illustrate certain embodiments. It will be apparent to those skilled in the art that these embodiments do not represent the full scope of the invention which is broadly applicable in the form of variations and equivalents as may be embraced by the claims appended hereto. Furthermore, features described or illustrated as part of one embodiment may be used with another embodiment to yield still further a 110, embodiment. It is intended that the scope of the claims extend to all such variations and equivalents.

[0022] The apparatus and method of the invention are particularly useful in the production of multicomponent fibers known as sheath-and-core fibers wherein the fiber’s geometric configuration of components is such that one polymeric component is substantially completely surrounded by another polymeric component. Such a sheath-and-core fiber as is known in the art is shown in FIG. 1. In FIG. 1, the multicomponent (in this case, bicomponent) fiber generally designated 10 is shown in cross section. The fiber 10 comprises a core component 16 and a sheath component 12. As shown in FIG. 1, each of the core component 16 and the sheath component 12 occupy about 50 percent of the total cross sectional area of the fiber 10. Depending on the physical properties, cost, processability and other parameters of the particular materials selected for the sheath component and the core component, it is often highly desirable to minimize the amount of one component used in relation to the other component. Shown in FIG. 2 is another sheath-and-core type multicomponent fiber in which the amount of sheath component has been reduced. In FIG. 2, the multicomponent fiber 20 comprises a core component 26 and a sheath component 22 and is therefore similar to the fiber 10 depicted in FIG. 1. However, for the fiber 20 in FIG. 2, the core component 26 occupies approximately 80 percent of the total cross sectional area of the fiber 20 while the sheath component 22 occupies only about 20 percent of the total cross sectional area of the fiber 20.

[0023] In other embodiments it may be desirable to still further reduce the amount of sheath component in relation to the core component. Such a fiber is depicted in FIG. 3, which illustrates a cross section of the multicomponent fiber 30 for which the core component occupies approximately 90 percent of the total cross sectional area of the fiber 30 while the sheath component 32 occupies only about 10 percent of the total cross sectional area of the fiber 30. It may be worth noting that for a sheath-and-core fiber having a 20 micron total diameter, when the sheath percentage is 10 percent of the total fiber cross sectional area, the thickness of the sheath is only about 0.5 microns. It may be still further desirable to produce sheath-and-core fibers having even lower percent-

[0024] An apparatus for the production of such sheath-and-core multicomponent fibers, and particularly multicomponent fibers having low and very low percentage of sheath component, is described below beginning with FIG. 4.

[0025] The apparatus for forming sheath-and-core fibers comprises a series of stacked distribution plates for distributing the components of the fiber in order to deliver the components to an extrusion capillary in the desired configuration and desired relative amounts. At the time of distribution, such components will be in fluid form such as fluidized polymers, for example molten thermoplastic polymers. The FIGS. 4-6 depict a portion of a first distribution plate designated generally 40. The distribution plate 40 is shown in top view in FIG. 4 and includes the center hole 42 that is a generally cylindrical channel drilled or otherwise formed through the depth of distribution plate 40 for accepting the core component polymer and conducting the core component polymer vertically (into the figure) into and through the distribution plate 40 toward the bottom surface (FIG. 6) of the distribution plate 40. The core component polymer is supplied to the first distribution plate 40 by a polymer supply such as a heated polymer supply pipe (not shown). Although not required, the distribution plate 40 may also desirably include a lateral channel 44 for conducting the core component polymer in a horizontal fashion, which allows for flexibility as to the placement of the connection of the polymer supply. Channel 44 may be milled or otherwise formed into the top surface of the distribution plate 40 to a desired depth but should not extend through the entire depth of distribution plate 40.

[0026] Also shown in FIG. 4 is a horseshoe- or generally semicircular-shaped lateral channel 46 for accepting the sheath component polymer and conducting the sheath component polymer laterally or in a generally horizontal fashion to the vertical holes 48 and 50 that are drilled or otherwise formed through the depth of distribution plate 40. The sheath component polymer is supplied to the first distribution plate 40 by a polymer supply such as a heated polymer supply pipe (not shown) at the portion of the lateral channel 46 marked A. That is to say that the sheath component polymer is desirably supplied at or near the center of the horseshoe-shaped lateral channel 46. The horseshoe-shaped lateral channel 46 may be milled or otherwise formed into the top surface of the distribution plate 40 to a desired depth but should not extend through the entire depth of distribution plate 40. After the horseshoe-shaped lateral channel 46 conducts the sheath component polymer to the vertical holes 48 and 50, vertical holes 48 and 50 conduct the sheath component polymer vertically through the distribution plate 40 toward the bottom surface (FIG. 6) of the distribution plate. Also shown in phantom in FIG. 4 are additional features located in the bottom surface of the distribution plate 40 which are described in more detail with reference to FIG. 6.

[0027] Turning to FIG. 5, the distribution plate 40 is shown in side view cut-away diagram with the cut taken along the line 2—2 shown in FIG. 4. In this view, the center hole 42 is visible as a hole completely through the vertical thickness of distribution plate 40. The side view of horse-
shoe-shaped lateral channel 46 is also visible, as is the optional channel 44, which as shown connects to center hole 42. As shown in FIG. 5, the horseshoe-shaped lateral channel 46 and the optional channel 44 are formed as partial depth channels in the top surface of distribution plate 40.

[0028] Turning to FIG. 6, the distribution plate 40 is shown in bottom view. The top surface features (horseshoe-shaped lateral channel 46 and optional channel 44) are shown in phantom. The center hole 42 terminates at the bottom surface of distribution plate 40. Holes 48 and 50 penetrate into the lateral channels 52 and 54 which are milled or otherwise formed into the bottom surface of the distribution plate 40 to a desired depth. Although not required, the lateral channels 52 and 54 desirably are slightly crescent-shaped, having a slight arc as shown.

[0029] Turning to FIGS. 7-9 there is shown a portion of a second distribution plate designated generally 70. The distribution plate 70 is shown in top view in FIG. 7 and includes the center hole 72 that is a generally cylindrical channel drilled or otherwise formed through the depth of distribution plate 70 for accepting the core component polymer and conducting the core component polymer vertically (into the figure) into and through the distribution plate 70 toward the bottom surface (FIG. 9) of the distribution plate. The top surface of distribution plate 70 is placed in face-to-face relation with the bottom surface of the distribution plate 40. The center hole 72 in distribution plate 70 is aligned with the center hole 42 in distribution plate 40. The core component polymer is supplied to the distribution plate 70 at its upper surface at center hole 72 by center hole 42 where it exits the bottom surface of distribution plate 40 shown in FIG. 6.

[0030] Also shown in FIG. 7 are the vertical holes 74, 76, 78 and 80 that are generally cylindrical channels drilled or otherwise formed through the depth of distribution plate 70. Because the top surface of distribution plate 70 is placed in face-to-face relation with the bottom surface of the distribution plate 40, the top surface of distribution plate 70 forms a "floor" or lower boundary for the crescent-shaped lateral channels 52 and 54 (FIG. 6), allowing the sheath component polymer to be conducted laterally from the terminus of vertical holes 50 and 48 (FIG. 6) to the ends of the crescent-shaped lateral channels 52 and 54 (FIG. 6). The vertical holes 74 and 76 (FIG. 7) are positioned to accept the sheath component polymer from the lateral or horizontal ends of the crescent-shaped lateral channel 54 (FIG. 6), and the vertical holes 78 and 80 (FIG. 7) are positioned to accept the sheath component polymer from the lateral or horizontal ends of the crescent-shaped lateral channel 52 (FIG. 6). The vertical holes 74, 76, 78 and 80 (FIG. 7) then conduct the sheath component polymer vertically through the distribution plate 70 toward the bottom surface (FIG. 9) of the distribution plate. Also shown (in phantom) in FIG. 7 is an annular cavity located in the bottom surface of the distribution plate 70 which is described in more detail with reference to FIG. 9.

[0031] Turning to FIG. 8, the distribution plate 70 is shown in side view cut-away diagram with the cut taken along the line 5—5 shown in FIG. 7. In this view, the center hole 72 is visible as a hole completely through the vertical thickness of the distribution plate 70. The side view of the vertical hole 78 is also visible. Turning briefly to FIG. 9, the distribution plate 70 is shown in bottom view. The vertical center hole 72 terminates near the bottom surface of the distribution plate 70. The vertical holes 74, 76, 78 and 80 terminate into the annular-shaped lateral channel 82 that is milled or otherwise formed into the bottom surface of the distribution plate 70 to a desired depth. Returning to FIG. 8, the annular-shaped lateral channel 82 formed into the bottom surface of the distribution plate 70 can be seen in side cut-away view. By terminating into the annular-shaped lateral channel 82, the vertical holes 74, 76, 78 and 80 deliver the sheath component polymer to the annular-shaped lateral channel 82 for lateral flow.

[0032] Also as can be seen in FIG. 8, the material of the distribution plate 70 comprising the inner portion of the annular-shaped lateral channel 82 has also been milled or cut or otherwise formed to a desired depth into the bottom surface of the distribution plate 70 to produce a small gap between the bottom surface of that portion of the distribution plate 70 and the upper surface of distribution plate 100 (shown in FIGS. 10 and 11) when the distribution plates 70 and 100 are placed in face-to-face relation. This gap forms a restriction zone 84 which forms a high pressure drop flow region for the sheath component polymer and thereby ensures substantially evenly distributed flow of the sheath component polymer towards the terminus of the center hole 72 which, in use, is conducting the core component polymer vertically through the stacked distribution plates.

[0033] The size of the restriction zone (depth and width) may vary depending on factors such as the viscosity of the fluid to be pumped through the restriction zone and the rate at which it is pumped. Generally the restriction zone will be from about 0.05 millimeters (mm) to about 0.4 mm in depth and more particularly, for use with many of the thermoplastic fiber forming polymers, the depth should be from about 0.05 mm to about 0.2 mm, and still more particularly, from about 0.05 mm to about 0.15 mm. The width (straight line radial distance from the inner edge of the annular channel 82 to the outer edge of the center hole 72) may also vary but generally will be from about 0.5 mm to about 3 mm or larger, and more particularly from about 1 mm to about 2 mm. From a practical standpoint the width will be limited by the desired number of spinning holes per unit area, because as the width is increased the potential number of spinning holes per unit area must decrease. However, and without wishing to be bound by theory, we believe that the distribution of the sheath component will be more even where the width of the restriction zone 84 is at least as large as the diameter of the center hole 72.

[0034] Turning to FIGS. 10-11 there is shown a portion of a third distribution plate designated generally 100. The third distribution plate 100 is shown in top view in FIG. 10 and includes the center hole 102 that is a generally cylindrical channel drilled or otherwise formed through the depth of distribution plate 100 for accepting both of the sheath component polymer and the core component polymer and conducting the component polymers vertically (into the figure) into and through the distribution plate 100 toward the bottom surface (not shown) of the distribution plate 100. The third distribution plate 100 is placed in face-to-face relation with the bottom surface of the distribution plate 70, with the center hole 102 in the distribution plate 100 aligned substantially centered with the center hole 72 in distribution plate 70. When placed in face-to-face relation with the
bottom surface of the distribution plate 70, the top surface of the distribution plate 100 forms the “floor” or lower boundary for both the annular-shaped lateral channel 82 and the restriction zone 84 (not shown in FIGS. 10-11).

[0035] In use, the shear component polymer is conducted through the distribution plate 70 to the annular-shaped lateral channel 82 via the vertical holes 74, 76, 78 and 80 and spreads laterally to fill the annular-shaped lateral channel. The shear component polymer is then distributed into and through the restriction zone 84 where it surrounds or envelopes the core component polymer which has been conducted vertically through the distribution plates 40 and 70 via center holes 42 and 72, respectively. The shear component polymer and the core component polymer then are conducted together in the sheath-and-core configuration into the center hole 102 of distribution plate 100. Center hole 102 conducts the components to a spin plate having an extrusion capillary for extruding the components as a sheath-and-core fiber. It should be noted that while center hole 102 may be of the same diameter as center hole 72 in distribution plate 70, it may also aid the fiber spinning process and therefore be more desirable to have the center hole 102 be either slightly (on the order of 10 percent) smaller or slightly larger than the center hole 72.

[0036] Although the embodiments above have been described with respect to a certain desired number of distribution plates, more or fewer distribution plates may be used to accomplish the invention. As an example, a combination distribution plate/spin plate may be used in place of the distribution plate shown in FIG. 11 used in conjunction with a separate spin plate. Such a combination distribution and spin plate is shown in cut-away side view in FIG. 12. The combination plate in FIG. 12 is similar to the distribution plate shown in FIG. 11 except it comprises at its upper portion a hole 122 similar to the center hole 102 of distribution plate 100. The center hole 122 leads to a counterbore portion 124 which tapers or narrows the diameter of center hole 122 to become an extrusion capillary 126 for spinning the components as a sheath-and-core fiber.

[0037] Although the invention has been described above with respect to a fluid distribution configuration for producing a single sheath-and-core multicomponent fiber, it should be noted that for efficient production of a number of fibers, the distribution plates and spin plates would typically be wider and longer than the portions shown in the Figures and would comprise a plurality of distribution pathways and extrusion capillaries. Generally speaking, such distribution plates and spin plates desirably are capable of producing from about 5 to about 400 fibers per square inch of plate area, more particularly from about 5 to about 100 fibers per square inch of plate area, and still more particularly form about 10 to about 30 fibers per square inch of plate area. As is known in the art, after being extruded the fiber or fibers may be quenched to solidify from the molten extruded state and/or drawn or attenuated by means such as being taken up on mechanical driven rollers or pneumatic drawing means, and further may be collected into a web upon a mat such as a moving forming surface and/or bonded to produce a bonded web structure.

[0038] In another embodiment, it may also be desirable to produce sheath-and-core fibers having a low percentage of sheath component, but also wherein the core component is offset from the center of the sheath-and-core fiber such as is known in the art as an eccentric core sheath-and-core fiber. Fibers of this type may be produced by constructing the distribution plates such that the holes 42, 72 and 102 are positioned in a slightly offset fashion with respect to the center of the annular-shaped lateral channel, such that the shear component polymer has a longer travel distance through the restriction zone to one side of the core than on the other side of the core. However, it should be noted that for very low sheath percentages, such as for example fibers having less than 15% sheath cross sectional area, this may result in incomplete envelopment of the core component polymer by the shear component polymer.

[0039] Although the embodiments of the invention have been described with respect to apparatus conventionally utilized in the melt extrusion of various types of thermoplastic fibers or filaments, we believe the invention is not limited thereto and may also be beneficially used in other types of fiber extrusion processes such as for example in flash spun fiber production processes and in solution spun fiber production processes. However, the embodiments of the invention have been described with respect to apparatus conventionally utilized in the melt extrusion of various types of thermoplastic filaments or fibers and, without desiring to be limited, we believe the invention is particularly well suited to the extrusion of thermoplastic fiber polymers. Polymers generally suitable for extrusion of fibers from a thermoplastic melt include the known polymers suitable for production of nonwoven webs and materials such as for example polyolefins, polyesters, polyamides, polycarbonates and copolymers and blends thereof. It should be noted that the polymer or polymers may desirably contain other additives such as processing aids or treatment compositions to impart desired properties to the fibers, residual amounts of solvents, pigments or colorants and the like. It should also be noted that while the components have been described herein in some instances as the sheath component “polymer” or the core component “polymer”, that either or both of the sheath component or core component may be multicomponent systems comprising more than one polymer in, for example, a blend of polymers.

[0040] Suitable polyolefins include polyethylene, e.g., high density polyethylene, medium density polyethylene, low density polyethylene and linear low density polyethylene; polypropylene, e.g., isotactic polypropylene, syndiotactic polypropylene, blends of isotactic polypropylene and atactic polypropylene; polybutylene, e.g., poly(1-butene) and poly(2-butene); polypentene, e.g., poly(1-pentene) and poly(2-pentene); poly(3-methyl-1-pentene); poly(4-methyl-1-pentene); and copolymers and blends thereof. Suitable copolymers include random and block copolymers prepared from two or more different unsaturated olefin monomers, such as ethylene/propylene and ethylene/butylene copolymers. Suitable polyamides include nylon 6, nylon 6/6, nylon 4/6, nylon 11, nylon 12, nylon 6/10, nylon 6/12, nylon 12/12, copolymers of caprolactam and alkylene oxide diamine, and the like, as well as blends and copolymers thereof. Suitable polyesters include poly lactide and poly lactic acid polymers as well as polyethylene terephthalate, polybutylene terephthalate, polytetramethylene terephthalate, polycyclohexylene-1,4-dimethylene terephthalate, and isophthalate copolymers thereof, as well as blends thereof.
In addition, many elastomeric polymers are known to be suitable for forming fibers or filaments. Elastic polymers useful in making extruded fibers may be any suitable elastomeric fiber forming resin including, for example, elastic polyesters, elastic polyurethanes, elastic polyamides, elastic co-polymers of ethylene and at least one vinyl monomer, block copolymers, and elastic polyolefins. Examples of elastic block copolymers include those having the general formula A-B-A or A-B, where A and A' are each a thermoplastic polymer endblock that contains a styrenic moiety such as a poly (vinyl arene) and where B is an elastomeric polymer midblock such as a conjugated diene or a lower alkene polymer such as for example polyisoprene-poly(ethylene-butylene)-polyisoprene block copolymers. Also included are polymers composed of an A-B-A-B tetrablock copolymer, as discussed in U.S. Pat. No. 5,332,613 to Taylor et al. An example of such a tetrablock copolymer is a styrene-poly(ethylene-propylene)-styrene-poly(ethylene-propylene) or SEPSSEP block copolymer. These A-B-A' and A-B-A-B copolymers are available in several different formulations from the Kraton Polymers of Houston, Tex. under the trade designation KRATON®.

Examples of elastic polyolefins include ultra-low density elastic polypropylenes and polyethylene, such as those produced by “single-site” or “metallocene” catalysis methods. Such polymers are commercially available from the Dow Chemical Company of Midland, Mich. under the trade name ENGAGE®, and described in U.S. Pat. Nos. 5,278,272 and 5,272,236 to Lai et al. entitled “Elastic Substantially Linear Olefin Polymers”. Also useful are certain elastomeric polypropylenes such as are described, for example, in U.S. Pat. No. 5,596,052 to Revee et al. and U.S. Pat. No. 5,596,052 to Reesene et al., incorporated herein by reference in their entirety, and polyolefinic such as AFFINITY® EG 8200 from Dow Chemical of Midland, Mich. as well as EXACT® 4049, 4011 and 4041 from Exxon of Houston, Tex., as well as blends.

A particularly advantageous use of the invention may be for the production of elastic web materials from elastomeric polymers. Elastic fibers and webs or other materials made from elastomerics often have unpleasent tactile aesthetic properties, such as feeling rubbery or tacky to the touch, making them unpleasant and uncomfortable for skin contacting uses. Fibers made from non-elastic polymers such as for example polyesters, non-elastic polyolefins and polyamides, on the other hand, have better tactile, comfort and aesthetic properties.

The tactile aesthetic properties of elastic polymers can be improved by forming a shear-and-core fiber wherein the tackiness or unpleasent skin feel of the elastic is improved or masked by sheathing an elastic core polymer with another non-elastic polymer such as the above described which have more pleasant aesthetic properties. Such sheathing with suitable thermoplastic polymers also reinforces the typically weak elastomer melt strength. That is, elastomeric polymers often have low melt strength and have a tendency to break during fiber melt drawing, and the presence of a non-elastic or lower elasticity but higher melt strength sheath can help prevent fiber breaks during drawing. In addition, a sheath of non-elastic polymer, being generally less tacky (once cooled or quenched from the molten state) than elastic polymers may thereby minimize the so-called “fiber roping” or tendency of tacky fibers to stick together when they touch during manufacture in typical high speed and high fiber density spinning lines. However, in order to obtain sufficient benefit of the elastic properties of the core component of the fiber, it is desirable that the elastic core should not be too thickly sheathed in non-elastic polymers. The invention is highly suited to producing shear-and-core fibers having a very low percentage of sheath component polymer and is therefore capable of producing fibers and webs having substantial elastic properties but where the undesirable attributes of the elastic material are sheathed in a thin “skin” of non-elastic polymer.

EXAMPLE

A series of distribution plates suitable for stacking into a shear-and-core fiber polymer distribution and extrusion apparatus were constructed by electroforming the various vertical and lateral channels of the distribution plates. Using the FIGS. 4-10 for reference, the distribution plates were constructed as follows. The distribution plates and spin plates were manufactured having about 20 extrusion holes per square inch and were therefore capable of producing shear-and-core fibers at about 20 holes per square inch of the apparatus.

The first distribution plate was substantially similar to distribution plate 40 shown in FIGS. 4-6 and was about 3 millimeters (mm) thick, having center holes 42 through the distribution plate which were about 0.4 mm in diameter and having the optional lateral channel 44 (about 1.6 mm long and about 0.8 mm deep) for conducting the core polymer to the center hole. The horseshoe- or generally semicircular-shaped lateral channels 46 were about 0.8 mm wide and about 0.8 mm deep and each led to the two vertical holes 48 and 50 which were also about 0.8 mm wide and spaced with their centers about 1.6 mm above and below (in the orientation shown in FIG. 4) each center hole. The bottom surface of the first distribution plate was substantially similar to that of distribution plate 40 shown in FIG. 6. Each vertical hole 48 and each vertical hole 50 terminated into a lateral channel which was about 0.8 mm deep and about 0.8 mm wide and which were about 3.6 mm long and had a slight arc as shown in FIG. 6.

The second distribution plate was substantially similar to distribution plate 70 shown in FIGS. 7-9 and was about 3 mm thick, having center holes 72 through the distribution plate which were about 0.8 mm in diameter and having the vertical holes 74, 76, 78 and 80 through the distribution plate that were also about 0.8 mm in diameter. For each center hole 72 the four vertical holes 74, 76, 78 and 80 were positioned at the four corners of a square with a center about 2.1 mm from the center of the center hole. The bottom surface of the second distribution plate was substantially similar to that of distribution plate 70 shown in FIG. 7. Each set of vertical holes 74, 76, 78 and 80 terminated into an annular-shaped lateral channel 82 that was just slightly wider than the diameter of the vertical holes 74, 76, 78 and 80 at about 0.85 mm wide, and was about 0.8 mm deep. The outer diameter of these annular-shaped lateral channels was about 5 mm and the inner diameter was about 3.3 mm. The material from the bottom surface of the second distribution plate comprising the inner portion of the annular-shaped lateral channel 82 was removed to a depth of about 0.1 mm, thereby producing for each annulus a restriction zone in the gap between the cut-away inner portion of the annulus and
the third distribution plate (when the bottom of the second plate was placed against the top surface of the third plate). This restriction zone was about 0.1 mm thick (deep) and about 1.3 mm long.

[0048] The third distribution plate was substantially similar to distribution plate 100 shown in FIGS. 10-11, about 3 mm thick and having center holes 102 through the distribution plate which were about 1 mm in diameter. The three distribution plates were placed in face-to-face relation in the order described and with the centers of their respective center holes centered. A spin plate having 1 mm diameter, 25 mm long counterbores leading to 0.6 mm diameter, 3.6 mm long extrusion capillaries was placed in face-to-face relation with the bottom surface of the third distribution plate, with the center of the counterbores (and extrusion capillaries) centered on the center holes 102. The distribution plates and the spin plate were secured by bolting through all the plates at the outer edges.

[0049] A commercially available polypropylene polymer designated Exxon 3155 and available from the Exxon Mobil of Houston, Tex. was melted by an extruder and supplied to the apparatus through a polymer supply pipe to provide the sheath component polymer for the sheath-and-core fiber. At the same time, a commercially available elastomeric styrenic block copolymer designated KRAFON G2755 and commercially available from KRAFON Polymers, LLC of Houston, Tex. was melted by a second extruder and supplied to the apparatus through a second polymer supply pipe to provide the core component polymer for the sheath-and-core fiber.

[0050] The two component polymers were pumped through the distribution and extrusion apparatus to produce sheath-and-core fibers. The two component polymers were pumped at relative volumetric pumping rates to obtain a 1:10 volumetric flow ratio of the non-elastic sheath component polymer to the elastic core component polymer. As the fibers were extruded from the spin plate they were quenched by directing chilled air at the fibers and the fibers were drawn in a pneumatic slot drawing unit and collected upon a moving forming surface to form a nonwoven web of the sheath-and-core fibers. The fibers had an average diameter of about 24 microns and were examined under a microscope to verify that the sheath component fully encircled the core component.

[0051] The nonwoven web of fibers collected on the forming surface was also stabilized by thermal point bonding at about 160° F. (about 70° C.) over about 8 percent of its surface with a Ramish bond pattern as described above. The stabilized nonwoven web thus produced exhibited the ability to recover a substantial portion of its original length upon release of a stretching force. For example, within 1 minute of a 100 percent extension the web had recovered about 100 percent following a machine-direction extension (that is, had recovered to about its original dimension after being extended to twice its original dimension). Also, within 1 minute following a 100 percent cross machine direction extension the web recovered about 50 percent (that is, had recovered about half of the amount it was extended). The nonwoven web was also exhibited good extensibility prior to break, being able to be extended up to 400 percent of its original cross machine direction dimension prior to rupturing and up to about 150 percent of its machine direction dimension prior to rupturing. However, due to the sheathing of non-elastic polymer on the elastic core of the fibers, the nonwoven web thus produced also had a pleasantly smooth and non-tacky feel to the touch, and the visual appearance of the formation of the web was much improved compared to similar webs spun from monocomponent fibers of elastic polymer.

[0052] While various patents have been incorporated herein by reference, to the extent there is any inconsistency between incorporated material and that of the written specification, the written specification shall control. In addition, while the invention has been described in detail with respect to specific embodiments thereof, it will be apparent to those skilled in the art that various alterations, modifications and other changes may be made to the invention without departing from the spirit and scope of the present invention. It is therefore intended that the claims cover all such modifications, alterations and other changes encompassed by the appended claims.

1. An apparatus for the production of extruded multicomponent fibers, said apparatus comprising:
   a) a series of stacked distribution plates, said stacked distribution plates comprising channels arranged to conduct a first fluid along at least one vertical flow path, and said stacked distribution plates comprising channels arranged to conduct a second fluid along first and second lateral flow paths, then along a plurality of vertical paths, then along a second plurality of lateral paths, then along a second plurality of vertical paths, said second plurality of vertical paths terminating in an annular-shaped lateral channel;
   b) a restriction zone for receiving said second fluid from said annular-shaped lateral channel, said restriction zone arranged between two of said stacked distribution plates; and,
   c) a spin plate comprising at least one extrusion capillary arranged to receive said first fluid and said second fluid.

2. The apparatus of claim 1 wherein said fiber is a sheath-and-core fiber having a fiber cross-sectional area comprising a sheath cross-sectional area and a core cross-sectional area, and wherein said restriction zone is adapted to result in a substantially continuous sheath around said core and wherein said sheath cross-sectional area is less than about 25 percent of said fiber cross-sectional area.

3. The apparatus of claim 2 wherein said sheath cross-sectional area is less than about 20 percent of said fiber cross-sectional area.

4. The apparatus of claim 3 wherein said sheath cross-sectional area is less than about 15 percent of said fiber cross-sectional area.

5. The apparatus of claim 4 wherein said sheath cross-sectional area is 10 percent or less of said fiber cross-sectional area.

6. The apparatus of claim 1 wherein said restriction zone comprises a depth and a width and wherein said depth is from about 0.05 millimeters to about 0.4 millimeters, and wherein said width is from about 0.5 millimeters to about 3.0 millimeters.

7. The apparatus of claim 6 wherein said depth is from about 0.05 millimeters to about 0.15 millimeters, and wherein said width is from about 1.0 millimeter to about 2.0 millimeters.
8. An apparatus for the production of extruded multicomponent fibers, said apparatus comprising:
   a) at least one extrusion capillary;
   b) a first distribution plate configured to conduct a first polymer along a vertical central path, and configured to conduct a second polymer along first and second lateral paths, then along a plurality of vertical paths, then along a plurality of lateral paths;
   c) a second distribution plate configured to conduct said first polymer along a vertical path, and configured to conduct said second polymer along a plurality of vertical paths, then along a plurality of lateral paths, said lateral paths forming an annular path, and said second distribution plate forming the upper portion of a restriction zone; and
   d) a third distribution plate forming the lower portion of said restriction zone and said third distribution plate configured to conduct said first polymer and said second polymer to said extrusion capillary.
9. A method for forming a sheath-and-core multicomponent fiber, said method comprising:
   a) providing a plurality of stacked distribution plates and a spin plate comprising a plurality of extrusion capillaries;
   b) providing a first fluidized polymer and a second fluidized polymer;
   c) conveying said first polymer along a first vertical path through said stacked distribution plates to said extrusion capillary;
   d) conveying said second polymer along second paths through said stacked distribution plates, said second paths terminating in an annular-shaped lateral channel;
   e) conveying said second polymer through a restriction zone between said annular-shaped lateral channel and said first vertical path to envelop said first polymer with said second polymer; and
   f) extruding said first polymer and said second polymer from said extrusion capillary.
10. The method of claim 9 wherein said first fluidized polymer and said second fluidized polymer are molten thermoplastic polymers.
11. The method of claim 10 wherein said first fluidized polymer is an elastomeric polymer.
12. The method of claim 11 wherein said second fluidized polymer is polyolefin.
13. The method of claim 9 wherein said sheath-and-core fiber comprises a fiber cross-sectional area comprising a sheath cross-sectional area and a core cross-sectional area, and wherein said restriction zone is adapted to result in a substantially continuous sheath around said core and wherein said sheath cross-sectional area is less than about 25 percent of said fiber cross-sectional area.
14. The method of claim 13 wherein said sheath cross-sectional area is less than about 15 percent of said fiber cross-sectional area.
15. The method of claim 14 wherein said sheath cross-sectional area is 10 percent or less of said fiber cross-sectional area.
17. A nonwoven web comprising a plurality of the fibers of claim 16.
18. A sheath-and-core fiber produced in accordance with the method of claim 11.
19. A nonwoven web comprising a plurality of the fibers of claim 18.
20. A sheath-and-core fiber produced in accordance with the method of claim 15.