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(54) **PROCESS AND APPARATUS FOR PRODUCING A VOLUMINOUS NONWOVEN FABRIC**

(57) The present invention relates to a process for producing a nonwoven fabric, comprising the steps of:
(a) extruding a plurality of filaments from a spinneret, said filaments being at least bicomponent filaments;
(b) depositing said filaments to form a nonwoven fabric on an element collecting the filaments;
(c) performing a bonding of said nonwoven fabric;
(d) increasing the thickness of said nonwoven fabric by crimping at least part of the filaments by heating said nonwoven fabric;
(e) preferably performing a setting of said nonwoven fabric;
wherein said steps (c) and (d) are performed substantially simultaneously by means of a heated calender.

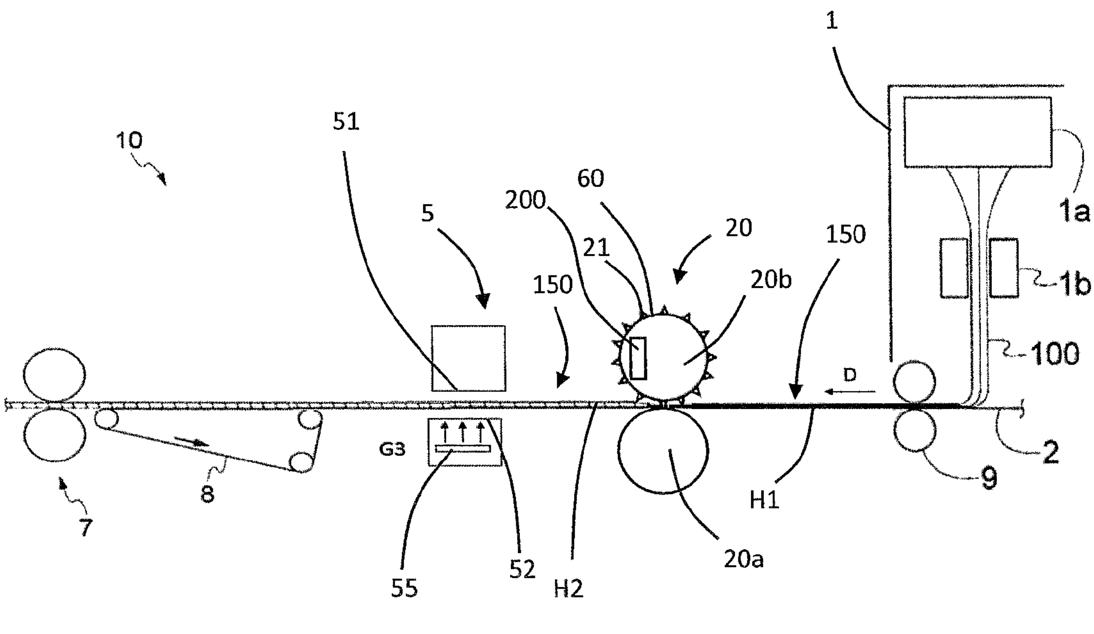

Fig. 1

EP 4 279 648 A1

Description

[0001] The present invention relates to a process and apparatus for producing a nonwoven fabric and, in particular, voluminous nonwoven fabrics obtained by spunbond process.

[0002] As known, spunbond fabrics are obtained by extruding, drawing and depositing a plurality of filaments of plastic material on a conveyor belt. The filaments deposited on the belt are then constrained or bonded together at a plurality of points, by means of different processes, such as for example calendering, applying air or water jets, or welding, etc.

[0003] A typical plant for producing spunbond filaments comprises a spinning head fed by extruders, a drawing unit and a deposition unit for depositing the drawn filaments on a movable support (collecting surface) where the nonwoven fabric is formed.

[0004] The nonwoven fabrics of spunbond type are used in various fields such as for example medical and sanitary ones, but also in the geotechnical field, in civil engineering, in building construction. Depending on the application, the nonwoven fabric must have different mechanical characteristics in terms of finishing, resistance to particular agents, etc., so as to meet the different requirements of the sectors of use.

[0005] Nonwoven fabrics made from filaments formed by of two or more components, so as to be able to exploit the different characteristics of the materials used, are known in the art.

[0006] It is known, for example, to arrange two polymer materials in side-by-side arrangement. In the side-by-side design, two polymer materials are coextruded so as to form a multicomponent filament in which the two materials form two sub-filaments next to each other. Typically, the multicomponent filament has circular section and the two sub-filaments have semicircular sections. In other words, the section of the contact surface between the two filaments substantially coincides with the diameter of the section of the multicomponent filament. It is also known to vary the ratio between the two components. In this case, the contact surface between the two sub-filaments coincides with a chord of the circular section of the multicomponent filament. Similar side-by-side filaments are described, for example, in US 5382400 and US 2013/0029555.

[0007] It is further known to select the materials of the two sub-filaments with different characteristics so as to cause the multicomponent filament to crimp. Such a design is used to provide the final nonwoven fabric with increased softness and volume, among other things.

[0008] For example, the two sub-filaments may be made of materials having different characteristics, whereby the multicomponent filament is initially extruded and drawn, thus forming a not-crimped continuous filament. When the multicomponent filament is deposited on the collector, the two sub-filaments behave in a different way, thus crimping the multicomponent filament.

[0009] Similarly, the two sub-filaments may be made of materials having different coefficients of thermal expansion. If the multicomponent filament is subjected to thermal treatment, the two sub-filaments expand/shrink in a different way with respect to one another, thereby crimping the multicomponent filament.

[0010] Additionally, it is known to make the two sub-filaments of materials different from one another resulting, during the extrusion and drawing step, in uneven stresses between the two sub-filaments that cause the multicomponent filament to be crimped.

[0011] Processes are known in which crimp develops prior to fiber deposition on the collecting belt, as described in US2009/0152757 and US2008/0210363 in the name of Reifenhauser. In fact, such documents teach to exploit a diffuser for activating the natural fiber crimp, the diffuser being arranged downstream of the means for drawing the filaments which are therefore deposited already crimped on the conveyor belt to be then further crimped by appropriate treatments (thereby making a so-called "primary comprising", before depositing, and a "secondary crimping", after depositing). However, the treatment of already crimped fibers is complex and does not achieve satisfactory results. Moreover, processes for crimping even materials having low co-adhesion properties, are known. For example, US 3458390 teaches to make side-by-side multicomponent filaments in which the contact surface between the two filaments generates a shape coupling (by means of "undercuts"), so as to mechanically constrain or entangle the sub-filaments to one another. Therefore, the two sub-filaments are joined by such mechanical constraint and do not split during the required treatments (for example thermal treatments). It is difficult to obtain such a shape. Moreover, excessive stress may cause the multicomponent filament to undesirably split. Finally, it is not known how to make a nonwoven fabric by such multicomponent filament.

[0012] The treatment of bicomponent fibers by means of ovens and similar elements, designed to heat the filaments of a nonwoven fabric, so as to cause the filaments to crimp as well as an increase in volume (thickness) of the nonwoven fabric, is further known. However, treatment in an oven involves a considerable amount of energy consumption.

[0013] Therefore, it is an object of the present invention to make a spunbond nonwoven fabric having high crimping level and thus high volume level. It is a further object of the present invention a spunbond method allowing this nonwoven fabric to be simply and economically produced.

[0014] The present invention achieves these and other objects by means of a process and apparatus according to the attached independent claims. Preferred aspects are set forth in the dependent claims.

[0015] According to an aspect of the present invention, a process for producing a nonwoven fabric comprises the steps of:

(a) extruding a plurality of filaments from a spinneret, said filaments being at least bicomponent filaments;
(b) depositing the filaments to form a nonwoven fabric on an element collecting the filaments;
(c) performing a bonding of said nonwoven fabric;
(d) increasing the thickness of the nonwoven fabric by crimping at least part of the filaments by heating the nonwoven fabric;
(e) preferably performing a setting of said nonwoven fabric.

[0016] In particular, steps (c) and (d) are performed substantially simultaneously by means of a heated calender. During steps (c) and (d), at least part of the filaments of the nonwoven fabric are subjected to bonding, that is, at least part of the filaments are thermally constrained together so as to provide the nonwoven fabric with at least partial consolidation and stabilization of the nonwoven fabric. At the same time, the calender provides enough space for the fibers of the nonwoven fabric (i.e., where the fibers are not subjected to bonding) that allows them to crimp so that, as a result, the thickness of the nonwoven fabric increases.

[0017] In more detail, the use of a heated calender allows at least a portion of the filaments to be entangled at some constraining points (or zones) of the nonwoven fabric and at least a portion of the filaments to crimp at points where they are not constrained to each other. Through such crimping, the volume (particularly the thickness) of the nonwoven fabric can then increase at the portions of the nonwoven fabric where the filaments are not constrained together, thus producing a voluminous nonwoven fabric. In addition, the calender allows a constraint between the filaments of the nonwoven fabric to be achieved.

[0018] In other words, thanks to the same element, i.e., the heated calender, both an increase in the volume of the nonwoven fabric and a partial consolidation thereof can be substantially simultaneously achieved.

[0019] According to a preferred aspect, the composition of the nonwoven fabric treated by the calender is substantially homogeneous, that is, each portion of the nonwoven fabric has essentially the same filament composition compared with the other portions of the nonwoven fabric. In other words, in the case of multiple types of filaments, they are present essentially in the entire nonwoven fabric. The preferred solution has a single type of filaments for the entire nonwoven fabric and they are configured to crimp due to heating.

[0020] Specifically, in preferred embodiments, the fabric is single-layered, so that the crimping of the filaments of a layer of nonwoven fabric is not limited by filaments (which do not crimp) of a different layer of fabric.

[0021] The nonwoven fabric treated by the calender is preferably not-bonded (i.e., it typically has a bonding area between 0% and 1%) before treatment by means of the heated calender. The device for extruding filaments (i.e., the device that forms the nonwoven fabric, comprising the aforementioned spinneret) may comprise a pair of rollers, usually smooth, arranged upstream of the heated calender. In such a case, this pair of rollers generally compacts the nonwoven fabric, without performing a bonding between the filaments thereof, so that the latter are free to crimp on the next heated calender.

[0022] In this regard, the heated calender is typically placed in the plant immediately downstream of the filament extruding device. Thus, between the filament extruding device and the heated calender there are no elements adapted to bond or heat the nonwoven fabric.

[0023] In particular, according to a possible aspect, the calender is configured to define on the nonwoven fabric a bonding area between 5% and 25%, more preferably between 7% and 18%. The concept of bonding area is well-known in the art and is commonly expressed as the (percent) ratio of the constrained area of nonwoven fabric in a surface unit to the area of that surface unit.

[0024] In other words, considering a portion of nonwoven fabric, the bonding area is the ratio of the sum of the constrained areas of nonwoven fabric in that portion to the area of the portion itself. For example, a 10% bonding area implies that, in a surface unit of the nonwoven fabric, 10% of the area of the nonwoven fabric portion is occupied by filaments constrained to each other, and 90% of the area of the nonwoven fabric is occupied by filaments not constrained to each other, i.e., not yet consolidated with each other.

[0025] The aforementioned preferred values of the bonding area allow a good balance between fabric consolidation and respective volume increase.

[0026] In other words, the bonding area is low enough to provide free space in the nonwoven fabric for the filaments to crimp, while at the same time ensuring sufficient consolidation of the fabric at the constraining points, that is, at the points where the filaments are consolidated with each other.

[0027] During the crimping step, in fact, the volume (particularly the thickness) of the nonwoven fabric increases at the portions that have not been constrained, i.e., entangled, to each other, while the thickness of the nonwoven fabric remains essentially unchanged at the bonding points or zones.

[0028] In order to make such a bonding area, the calender typically has protrusions, that is, there are protrusions on the surface of at least one of the rollers forming the calender. Typically, the calender comprises a pair of rollers, in which a roller has protrusions whereas the remaining roller has a smooth surface, which therefore typically acts as a countering surface for the protrusions, i.e., the nonwoven fabric treated by the calender is compressed into the space between the protrusions of the first roller and the substantially smooth surface of the second roller. According to a possible aspect, the calender has less than 50 protrusions per cm^2, preferably less than 40 protrusions per cm^2, more preferably between 5 and 30 protrusions per cm^2. The number of protrusions per surface unit of the calender contributes to define the bonding area that the calender can provide to the nonwoven fabric. Specifically, the bonding area is typically proportional to the number of protrusions per surface unit of the heated calender.

[0029] According to a possible aspect, during the treatment of the nonwoven fabric, the calender is heated to a temperature higher than 100°C, more preferably higher than 130°C, even more preferably to a temperature of about 160°C.

[0030] The calender temperature is typically chosen according to the type of polymer used in filament production, and in particular according to the melting and/or softening points of the polymers used in the production of the nonwoven filaments. Preferably, the calender is heated to a temperature above the softening point of one of the materials that form the filaments of the nonwoven fabric, typically above the melting point of one of the materials that form the filaments.

[0031] According to a possible aspect, before the treatment by the heated calender, the filaments are in an essentially non-crimped condition, that is, the filaments begin to crimp at the heated calender.

[0032] It should be noted that the difference between the crimped and non-crimped condition of a filament is known to the field technician and, in particular, in a non-crimped condition the filaments are substantially devoid of crimps. Some crimped filaments, on the other hand, have a plurality of crimps and a wavy, irregular pattern such that the length of a crimped filament is significantly less than the length of the same filament in the non-crimped condition.

[0033] The filaments of the present invention are therefore deposited in a preferably non-crimped manner. Therefore, when the non-crimped filaments are deposited, they exhibit a "crimp percentage" typically greater than 50 percent, and preferably greater than 70 percent. The "crimp percentage", known in the art, can be for example measured by making two signs spaced from one another on a filament to be tested and measuring the distance between the two signs along a straight line. The same filament is then extended (i.e. made straight) and the distance between the two signs is measured again. The percentage ratio between the first value and the second value of the distance, as known, is the value of the "crimp percentage".

[0034] A further definition of crimped filaments is provided, for example, in Reifenhauser Patent Application US20090152757, according to which crimped filaments are considered those having a radius of curvature less than 5 mm in the relaxed state.

[0035] According to a possible aspect, following step (d) in which by passing through a heated calender the thickness of the nonwoven fabric increased, the nonwoven fabric undergoes a cooling step. Such a step can, for example, help to set the properties of the nonwoven fabric and also to prevent heated filaments from adhering to the device that moves the nonwoven fabric.

[0036] According to a possible aspect, the cooling step is carried out by cooling means comprising at least one of: a cooling device configured to direct a gas flow against the nonwoven fabric at a temperature between 30°C and 140°C, for example; a suction roller; a cooled conveyor belt.

[0037] A cooling device configured to direct a flow of gas against the nonwoven fabric can be configured to direct a gas flow along a direction incident, preferably substantially perpendicular, to the nonwoven fabric. A suction roller can be equipped with an air suction system, so as to simultaneously attract and cool the nonwoven fabric. A cooled conveyor belt can be cooled by means known in the art and not described in detail herein, for example air suction means can be used.

[0038] According to a possible aspect, step (e) of setting the nonwoven fabric comprises additional calendering of the nonwoven fabric. Such additional calendering allows additional cohesion to be performed at several points in the nonwoven fabric.

[0039] According to a possible aspect, the filaments extruded from the spinneret in step (a) are at least bicomponent filaments. Such bicomponent filaments comprise two sub-filaments adhered to each other. Typically, the two sub-filaments are extruded according to a side-by-side configuration so as to form, between the two sub-filaments, a contact surface which, in the filament cross-section, has at least one inflection point so as to provide a substantially wavy conformation. The two sub-filaments are preferably made of materials having different melting temperature and/or different viscosity.

[0040] The combination of side-by-side sub-filaments characterized by different melting points is able to cause an increase in the crimping of the multicomponent filaments, as a result of a thermal treatment.

[0041] A further aspect of the present invention relates to a calender for the treatment of nonwoven fabrics, comprising heating elements and configured to define, on a nonwoven fabric, a bonding area between 5% and 25%, more preferably between 7% and 18%, and characterized by having a number of protrusions lower than 50 protrusions per cm^2, more preferably lower than 40 protrusions per cm^2, even more preferably between 5 and 30 protrusions per cm^2. As discussed, the heating elements allow heat treatment to be performed on the fabric, while the bonding area gives the filaments thereof enough space to crimp, so that the volume (thickness) of the nonwoven fabric can be increased. Such heating elements preferably comprise a fluidic circuit inside the calender in which a heated liquid, typically diathermal oil, flows. Alternatively, for example, calenders heated by electric means are known.

[0042] The protrusions on the calender may have different shapes in different embodiments of the present invention. For example, the protrusions can be substantially shaped as a cylinder, truncated cone, truncated pyramid. As described above, the density of protrusions on the outer surface of the calender contributes to define the bonding area of the nonwoven fabric treated with the calender itself. The area of the calender surface without protrusions allows the thickness of the nonwoven fabric to be increased because crimping of at least part of the nonwoven fabric filaments is allowed in that area.

[0043] A further aspect of the present invention relates to an apparatus for making a nonwoven fabric, comprising a spinneret for extruding a plurality of filaments and collecting means to collect the filaments and form a nonwoven fabric, a calender heated according to one or more of the aspects discussed above and a device for thermal treatment and at least one setting device.

[0044] According to a possible aspect, the spinneret of the apparatus is configured so as to extrude a bicomponent filament comprising two sub-filaments arranged in a side-by-side configuration in which, in cross section, the contact surface between the two sub-filaments has at least one inflection, so as to define a substantially wave-like shape.

[0045] According to a possible aspect, the collecting means to collect filaments are typically in the form of a conveyor belt or the like, are typically perforated or otherwise gas permeable. Appropriate means, not shown in detail and typically in the form of aspirator or similar element, can be provided below the filament collecting means so that a depression is created at the zone in which the filaments are deposited on the filament collecting means.

[0046] According to a possible aspect, the heated calender for nonwoven fabrics, as described earlier, is characterized by having heating elements that allow the calender to be heated. Such a calender is also characterized by protrusions that allow the bonding of the nonwoven fabric to be performed. In areas where no bonding of the nonwoven fabric occurs, the action of the heated calender allows an increase in thickness of the nonwoven fabric by crimping at least part of the filaments of the nonwoven fabric.

[0047] According to a possible aspect, various setting or bonding devices are known in the art and can be used in the present invention so as to consolidate the bulked layer of the nonwoven fabric.

[0048] According to a preferred aspect, the setting device may comprise an additional calender equipped with reliefs so as to impart additional embossing to the nonwoven fabric.

[0049] An additional aspect of the present invention further relates to a nonwoven fabric as obtainable by a process according to one or more of the aspects discussed above, wherein the nonwoven fabric comprises a number of constrained areas between 4 and 50 per cm^2, preferably between 4 and 40 per cm^2, more preferably between 5 and 30 per cm^2, so as to preferably define a bonding area between 5% and 25%, more preferably between 7% and 18%.

[0050] Hereinafter, referring to the appended figures, exemplary and non-limiting embodiments of the present invention will be described, in which:

- figure 1 is a schematic view of an apparatus for producing a nonwoven fabric according to a first embodiment;
- figure 2 shows a top schematic view of a nonwoven fabric of figure 1;
- figures 3A, 3B are sectional views of possible filaments that can be used to form a nonwoven fabric with an apparatus according to the present invention.

[0051] An apparatus 10 for producing a nonwoven fabric 150 comprises, in a known manner, a device 1 for extruding continuous filaments 100 and collecting means 2 for depositing and moving continuous filaments 100 in a forward direction D. Various devices 1 known in the art can be used for the purpose. For example, the devices described in Patent Applications WO2008/072278 and WO2008/075176 can be used.

[0052] In general, such devices have a spinneret 1a for extruding a plurality of filaments 100, typically followed by a drawing unit 1b. Generally, a cooling zone, not shown and known per se in the art, is arranged upstream of the drawing unit to direct air flows toward the filaments 100 after the extrusion from the spinneret 1a, so that they are cooled appropriately. Patent EP1939334, for example, describes a possible cooling chamber that can be used in the present invention; this Patent describes also a device for extruding and collecting filaments which is adapted to be used in the present invention.

[0053] At its outlet (i.e., the portion from which the nonwoven fabric exits the device 1), the device 1 comprises a pair of rollers 9, wherein the rollers are typically provided with a smooth outer surface. Passing the filament layer through the two rollers 9 allows the filaments of the nonwoven fabric to be compacted. At least one of the rollers 9 can be heated, so as to carry out a first step of crimping at least one portion of the filaments 100, thereby allowing an initial increase in the volume (thickness) of the nonwoven fabric 150. Typically, the rollers 9 are configured so as to avoid forming a bonding between the filaments 100. In particular, the heating temperature of the rollers 9 is preferably lower than the heating temperature of the calender 20, which is better described below. Preferred temperatures for the rollers 9 are between 50°C and 140°C, typically around 90°C and in any case chosen according to the nature of the polymers used, i.e., typically lower than at least the melting temperature of the materials forming the filaments 100.

[0054] Moreover, according to a preferred aspect, the coupling between the rollers 9 and the nonwoven fabric preferably prevents, or at least limits, the inflow of ambient air into the device 1 at the collecting means 2.

[0055] The continuous filaments 100 can have different shapes. In a preferred implementation the continuous filaments 100 are bicomponent filaments, i.e. they have two sub-filaments 100a, 100b coupled to one another. The bicomponent filament 100 can take different configurations, such as core-sheath or, more preferably, side-by-side.

[0056] According to an aspect of the present invention shown in the figures, the filaments 100 comprise two sub-filaments 100a, 100b made by coextruding two materials, typically polymers. The sub-filaments 100a, 100b are arranged in side-by-side configuration. A particular configuration of the filaments 100 is described in detail in the co-pending Application EP16198713.

[0057] In particular, the materials for the two sub-filaments 100a, 100b are preferably selected among PP, coPP, PE, CoPE, PET, CoPET, PA, PLA. Preferred combinations are: PP/PE, PP/CoPP, PP/PP, PET/PP, PET/CoPET, PA/PP, PLA/PP, PLA/PE. According to a preferred embodiment, the materials of the sub-filaments 100a, 100b are selected so as to allow them to crimp during a heat treatment. This is preferably achieved by at least one of the following characteristics: the difference between the melting temperature of the sub-filaments 100a and the melting temperature of the sub-filaments 100b is different by at least 10°C, and preferably by at least 20°C; the two materials of the sub-filaments 100a, 100b have different viscosity, preferably with a difference of more than 20%, when measured by the same method and under the same conditions. For example, the two materials can be tested with the same viscometer (e.g., rotational or capillary viscometer) or, more generally, the viscosity can be determined by a common method defined in a recognized standard (e.g., ASTM D3835). In other words, for the sub-filaments, polymers having different melting point and similar viscosity or polymers with equal or similar melting point but different viscosity, or else two polymers having different melting points and viscosity, can be selected. As mentioned, the preferred configuration of the two sub-filaments 100a, 100b is the side-by-side one in which the two sub-filaments are provided next to each other so that, in section, the two sub-filaments 100a, 100b are divided by a line representing the contact surface 105. According to a preferred aspect of the invention, the contact surface 105 has at least one inflection so as to define a wavy shape. In other words, the contact surface has a shape that shows at least one peak 3, 32 alternating with at least one trough 33. As known, "peaks" and "troughs" are the crests 3, 32, 33 formed by the wave, i.e. the maxima and the minima. The peaks 3, 32 are directed in the opposite direction with respect to the troughs 33. It should be noted that, typically, the difference between the troughs 33 and the peaks 3, 32 is given only by the orientation chosen for the section of the filament.

[0058] Preferably, the section of the contact surface 105 forms a wave with at least two crests 3, 32, 33; in particular, in preferred embodiments there are exactly three crests 3, 32, 33. For convenience's sake, two peaks and one trough will be referred to.

[0059] Preferably, the period T of the wave is between 40% and 100% of the length of the diameter of the multicomponent filament 100. It should be noted that for convenience's sake, reference will be made to the "diameter" of the multicomponent filament 100. However, the following description can be applied also to the case of a not-circular filament section. In this case, the "diameter" should be considered as the greatest dimension of the section. If the troughs 33 and the peaks 3, 32 have the same length, then as a result the length of each trough and peak is preferably between 20% and 50% of the diameter (or between 1/5 and 1/2 of the diameter).

[0060] As known, the period "T" of the wave is the sum of the lengths of a tough and a peak. The period T may also be measured as the distance between two subsequent peaks (or toughs).

[0061] Preferably, the contact surface 105 changes at least once its curvature, i.e. has at least one inflection. Typically, the section of the contact surface covers at least one period of the waveform. More preferably, the contact surface has at least two peaks and one trough, thus covering at least 1.5 periods of the waveform. Preferably, the waveform meets the edge of the filament section at a middle point between trough and peak, i.e. far from the trough and/or the peak adjacent to the edge.

[0062] In a preferred embodiment shown in figure 3A, the wave shape is substantially sinusoidal. Note that, given the small size of the filament section, the waveform will actually approximate to a sinusoid. Specifically, the ideal shape of the section of the filament 100, having a length of 1.5 periods and a strictly sinusoidal shape, is shown in Figure 3A. Figure 3B shows a possible real pattern of the section of the contact surface 105, with the wavelength of the contact surface slightly longer than the period T, the peaks cut off at the edge of the section and the wave shape approximating a sinusoid without strictly complying with its geometrical parameters.

[0063] Below the device 1 there are collecting means 2, typically in the form of a conveyor belt or the like, that allows the filaments 100 to be transported in a forward direction D. The collecting means 2 are typically perforated or otherwise gas permeable. Appropriate means, not shown in detail and typically in the form of aspirator or similar element, can be provided below the collecting means 2 so that a depression is created at the zone in which the filaments 100 are deposited on the collecting means 2 themselves.

[0064] The apparatus 10 is configured so as to form a substantially homogeneous nonwoven fabric in which the composition of filaments is substantially constant throughout the entire volume of the nonwoven fabric. Typically, the entire volume of the nonwoven fabric is formed by a single type of filament. The nonwoven fabric is therefore preferably single-layered, or otherwise formed by several layers having composition identical to one another.

[0065] The apparatus 10 further comprises a heated calender 20 downstream of the device 1 for extruding filaments 100.

[0066] Preferably, the heated calender 20 is typically arranged immediately downstream of the device 1 for extruding filaments 100. Specifically (excluding any cooling performed by the collecting means), the apparatus does not have any devices adapted to thermally treat, specifically heat, and/or bond, the nonwoven fabric arranged between the device 1 for extruding filaments 100 and the heated calender 20.

[0067] This heated calender 20 comprises a plurality of rollers 20a, 20b, preferably a pair of rollers 20a, 20b, and heating elements 200. The heating elements 200 preferably comprise a fluidic circuit which is arranged inside the heated calender 20 and in which a heated liquid, typically diathermal oil, flows. However, alternative heating elements are possible, such as electric means adapted to heat the calender 20.

[0068] Protrusions 21 extend on the outer surface 60 of at least one of the rollers 20b. Typically, the heated calender 20 has a pair of rollers 20a, 20b, in which a first roller 20b has protrusions on its surface, while the second roller 20a has a substantially smooth surface. As discussed, the smooth surface acts as a countering element for the protrusions 21 of the other roller. Typically, moreover, the roller with the protrusions 21 is the one arranged, in use, above the nonwoven fabric 150.

[0069] This heated calender 20 is configured to define a bonding area between 5% and 25%. As discussed, the bonding area is a concept known in the art as the ratio (typically expressed as a percentage) of the sum of the constrained areas 2011 (i.e., the areas of the nonwoven fabric where the filaments are subject to constraints) in a surface unit to the area of the surface unit 202 of the nonwoven fabric 150.

[0070] According to a possible aspect, the bonding area is between 5% and 25%, more preferably between 7% and 18%.

[0071] In a known way, the surface unit can be chosen as any area, preferably square shaped, whose dimensions may contain a significant number of constrained areas 2011. A preferred surface unit for calculating the bonding area is an area on the surface of the nonwoven fabric having dimensions D1 equal to 10 cm and D2 equal to 10 cm.

[0072] In general, the bonding area can be calculated as the ratio of the sum of the constrained areas 2011 in the surface unit to the area of the surface unit 202 of the nonwoven fabric 150 itself, which is calculated, in the case of a square unit, as D1 multiplied by D2.

[0073] The bonding area can be expressed as a percentage by multiplying by a factor of 100 said ratio of the sum of the constrained areas 2011 to the area of the surface unit 202 of the nonwoven fabric 150.

[0074] According to a possible aspect, the heated calender 20 comprises a plurality of rollers, preferably a pair of rollers 20a, 20b. The outer surface 60 of at least one of the rollers 20a, 20b, is provided with protrusions 21. The ratio of the number of protrusions 21 on the outer surface 60 of a roller 20a, 20b to the outer surface 60 of the same roller defines the amount of protrusions 21 per surface unit. According to a possible aspect, the number of protrusions 21 per cm^2 is between 4 and 50 protrusions per cm^2, preferably between 4 and 40 protrusions per cm^2, more preferably between 5 and 30 protrusions per cm^2.

[0075] The number of protrusions 21 per cm^2, i.e. the density of protrusions 21, contributes to define the bonding area since the greater the number of protrusions 21, the greater the number of constrained areas 2011, i.e. the greater the numerator of the formula discussed above to calculate the bonding area.

[0076] Typically, the number of protrusions 21 per cm^2 of the calender corresponds to the density of the constrained areas 2011 formed on the nonwoven fabric 150 by means of the heated calender 20 itself.

[0077] As a result, according to a preferred aspect, the nonwoven fabric 150 comprises a number of constrained areas 2011 between 4 and 50 per cm^2, preferably between 4 and 40 per cm^2, more preferably between 5 and 30 per cm^2.

[0078] Typically, the apparatus 10 comprises a cooling device 5 arranged downstream of the heated calender 20.

[0079] Various types of cooling devices can be used. For example, according to a possible aspect, a cooling device 5 may be equipped with means 55 to direct a gas flow G3, preferably air, against the nonwoven fabric. Preferably, the temperature of the gas flow G3 is between 30 and 140°C.

[0080] For example, a cooling device may comprise a surface 51, 52, and preferably two surfaces 51, 52, arranged parallel to the forward direction D of the nonwoven fabric 150, and preferably movable. The cooling device 5 can be configured so as to emit or suction gas G3 from at least one of these surfaces.

[0081] The direction of the gas flow G3 can be incident to the nonwoven fabric 150 and preferably substantially perpendicular to the nonwoven fabric 150. Preferably, the gas flow G3 is typically oriented so as to pass through the nonwoven fabric in the opposite direction with respect to the gravity, that is, from bottom to top, although the possibility of directing the gas flow G3 from top to bottom is not excluded.

[0082] Additionally or alternatively, the apparatus 10 comprises a suction roller, not shown in the figures, equipped with an air suction system, so as to simultaneously attract and cool the nonwoven fabric 150.

[0083] Additionally or alternatively, the apparatus 10 may comprise a cooled conveyor belt 8 to cool the nonwoven fabric 150 by means known in the art and not described in detail herein, such as by air suction means.

[0084] Downstream of the heated calender 20, considering the forward direction D of the nonwoven fabric 150, and possibly also downstream of the at least one cooling device 5, if any, the apparatus 10 typically comprises an additional setting device 7. Various setting devices are known in the art and can be used in the present invention so as to further consolidate the nonwoven fabric 150.

[0085] According to a preferred aspect, the setting device 7 comprises a second calender. This second calender may have reliefs so that additional embossing can be imparted to the nonwoven fabric 150 in order to perform further cohesion at different points of the nonwoven fabric 150.

[0086] Some filaments 100, in use, are extruded from the spinneret 1a and deposited on the collecting means 2, typically after being passed through a drawing unit 1b.

[0087] Preferably, the filaments 100 are deposited in a non-crimped condition on the collecting means 2, that is, they are essentially devoid of crimps when deposited on the collecting means 2. Thus, the thickness H1 of the nonwoven fabric 150 deposited on the collecting means 2 is typically comparable to that of standard spunbond nonwoven fabrics made from single-component or bicomponent filaments.

[0088] As described above, the filaments 100 are bicomponent filaments typically comprising two sub-filaments 100a, 100b next to each other in a side-by-side configuration, with the contact surface preferably wave-shaped when viewed in cross section.

[0089] Referring to figure 3A, a possible method for obtaining a wave shape is now described in detail. In particular, the first sub-filament 100a is extruded under a constant pressure P1. The extrusion pressure, i.e. the spinning pressure, of the second sub-filament varies, for example in a sinusoidal way, between to values P0 and P2. P0 is less than P1, whereas P2 is greater than P1. The second sub-filament 100b forms a protrusion within the first sub-filament P1, where the second sub-filament is extruded under pressure P2 (or under a pressure higher than the pressure of the first sub-filament 100a). Conversely, the first sub-filament forms a protrusion within the second sub-filament 100b, where the second sub-filament 100b is extruded under a pressure P0 (or a pressure lower than the pressure of the first filament).

[0090] For the sake of simplicity, an embodiment in which only the pressure of one of the two sub-filaments 100b is varied, has been described. However, in order to obtain a desired shape (e.g. wavy), the extrusion pressure can be varied at different areas of both the sub-filaments 100a, 100b. Generally, the second sub-filament forms a protrusion within the first sub-filament and vice versa, where the pressure of the second sub-filament is greater than the pressure of the first sub-filament.

[0091] When deposited on the collecting means, the filaments 100 form a nonwoven fabric 150 with thickness H1.

[0092] In particular, the filaments 100 are deposited on the belt in a random manner that results in a disordered distribution but substantially uniform density of the filaments. Preferably, as the nonwoven fabric exits the device 1, it passes between two rollers 9 typically provided with smooth outer surfaces. This allows the filaments of the nonwoven fabric to be compacted. Furthermore, according to a possible aspect, by heating at least one of the two rollers 9, a first step of crimping at least one portion of the filaments 100 can be further carried out, thereby allowing an initial increase in the volume (thickness) of the nonwoven fabric 150. As discussed, the temperature of the rollers 9 is typically chosen so as to avoid forming a bonding between the filaments 100. As discussed, in a preferred solution, the upper cylinder can be provided with means to heat it to a temperature preferably between 50°C and 140°C, usually around 90°C and in any case chosen according to the nature of the polymers used and able to provide a first cohesion of the filaments.

[0093] The coupling between the rollers 9 and the nonwoven fabric preferably prevents, or at least limits, the inflow of ambient air into the device 1 at the collecting means 2.

[0094] The nonwoven fabric 150 is treated so that its volume (thickness) is increased by means of a heated calender 20 equipped with protrusions 21.

[0095] By passing the nonwoven fabric 150 through the heated calender 20, a plurality of constrained areas 2011 can be obtained on the nonwoven fabric, i.e. areas in which the filaments 100 are constrained to each other. The spaces between these constrained areas 2011 allow the filaments to crimp in these spaces. As a result of this filament crimping, the nonwoven fabric increases its volume and in particular achieves a thickness H2 that is greater than the thickness H1 of the nonwoven fabric 150 before the calendering process. The thickness H2 of the nonwoven fabric 150 increases, as described above, at the zones that have not been constrained, i.e., entangled by the protrusions 21 of the heated calender 20. The increase in thickness H2 is therefore "driven" by defining the constrained areas 2011.

[0096] It should also be noted that, preferably, the composition of the filaments 100 in the nonwoven fabric is basically uniform. In a preferred embodiment, all filaments 100 of the nonwoven fabric have the same composition, so they can be all crimped by the heated calender 20.

[0097] The final layout of the nonwoven fabric can be determined by appropriately selecting the distribution of the protrusions 21, as this actually helps to define the bonding area and, accordingly, the possibility of increasing the thickness H2.

[0098] Preferably, the nonwoven fabric 150 is cooled, for example by one or more of the above-described cooling devices 5, vacuum roller and cooled conveyor belt 8. The cooling device 5 is configured to direct a gas flow G3 against the nonwoven fabric 150 in which said gas flow G3 is directed along a direction incident, preferably substantially perpendicular, to the forward direction of the nonwoven fabric 150. A suction roller, not shown in figure, can be equipped with an air suction system, so as to simultaneously attract and cool the nonwoven fabric 150 by suction. A cooled conveyor belt 8 can be cooled by means known in the art and not described in detail herein, for example air suction means can be used.

[0099] The nonwoven fabric 150 exiting the heated calender 20 can be treated by an additional setting device 7 such as a calender, where the nonwoven fabric 150 is consolidated.

Claims

1. Process for producing a nonwoven fabric (150), comprising the steps of:

    (a) extruding a plurality of filaments (100) from a spinneret (1a), said filaments being at least bicomponent filaments;
    (b) depositing said filaments (100) to form a nonwoven fabric (150) on an element collecting the filaments;
    (c) performing a bonding of said nonwoven fabric (150);
    (d) increasing the thickness (H2) of said nonwoven fabric (150) by crimping at least part of the filaments (100) by heating said nonwoven fabric (150);
    (e) preferably performing a setting of said nonwoven fabric (150);

    wherein said steps (c) and (d) are performed substantially simultaneously by means of a heated calender (20).

2. Process according to claim 1, wherein the composition of the nonwoven fabric treated by the calender in said step (d) is substantially homogeneous.

3. Process according to claim 1 or 2, wherein all filaments (100) of the nonwoven fabric have same composition, so that they can be crimped by the heated calender (20) in said step (d).

4. Process according to one of the preceding claims, wherein said calender is configured to define, on the nonwoven fabric, a bonding area between 5% and 25%, more preferably between 7% and 18%.

5. Process according to one of the preceding claims, wherein said calender has a plurality of protrusions (21), the number of said protrusions (21) being between 4 and 50 protrusions per cm^2, preferably between 4 and 40 protrusions per cm^2, more preferably between 5 and 30 protrusions per cm^2.

6. Process according to one of the preceding claims, wherein said calender is heated to a temperature higher than 100°C, more preferably higher than 130°C, even more preferably to a temperature of about 160°C.

7. Process according to one of the preceding claims, comprising a step of cooling said nonwoven fabric (150) following said step (d).

8. Process according to claim 7, wherein said cooling step is performed by cooling means (5, 8) comprising at least one of:

    - a cooling device (5) configured to direct a gas flow (G3) against said nonwoven fabric (150) at a temperature between 30 and 140°C.
    - a suction roller;
    - a cooled conveyor belt (8);

9. Process according to any one of the preceding claims, wherein said setting step (e) comprises additional calendering.

10. Process according to any one of the preceding claims, wherein during said step (a), a plurality of bicomponent filaments (100) comprising two sub-filaments (100a, 100b) adhered to each other are extruded, said two sub-filaments (100a, 100b) being extruded according to a side-by-side configuration, so as to form a contact surface (105) between said two sub-filaments which, in cross-section of the filament, has a substantially wave-like shape, said two sub-filaments (100a, 100b) preferably being made of materials having different melting temperature and/or different viscosity, said temperature difference being preferably at least 10°C and/or said viscosity difference being preferably greater than 20% when measured by the same method under the same conditions.

11. Calender (20) for the treatment of nonwoven fabrics, comprising heating elements (200) and configured to define, on a nonwoven fabric, a bonding area between 5% and 25%, more preferably between 7% and 18%, said calender preferably comprising a number between 4 and 50 protrusions per cm^2, more preferably between 4 and 40 protrusions per cm^2, even more preferably between 5 and 30 protrusions per cm^2.

12. Use of a calender according to claim 11, to crimp the filaments of a nonwoven fabric, preferably of a nonwoven fabric in which all the filaments have the same composition.

13. Apparatus (10) for producing a nonwoven fabric (150), comprising a device (1) for extruding filaments (100) equipped with a spinneret (1a) for extruding a plurality of filaments (100), and collecting means (2) to collect the filaments (100) and form a nonwoven fabric (150), a calender (20) heated according to claim 11, and preferably an additional setting device (7).

14. Apparatus (10) according to claim 13, wherein the heated calender (20) is arranged immediately downstream of the device (1) for extruding filaments (100), so that the nonwoven fabric does not undergo thermal and/or bonding treatments between the device (1) for extruding filaments (100) and the heated calender (20).

15. A nonwoven fabric (150) as obtainable by a process according to one of preceding claims 1 to 10, wherein said nonwoven fabric (150) comprises a number of constrained areas (2011) between 4 and 50 per cm^2, preferably between 4 and 40 per cm^2, more preferably between 5 and 30 per cm^2, so as to preferably define a bonding area between 5% and 25%, more preferably between 7% and 18%.

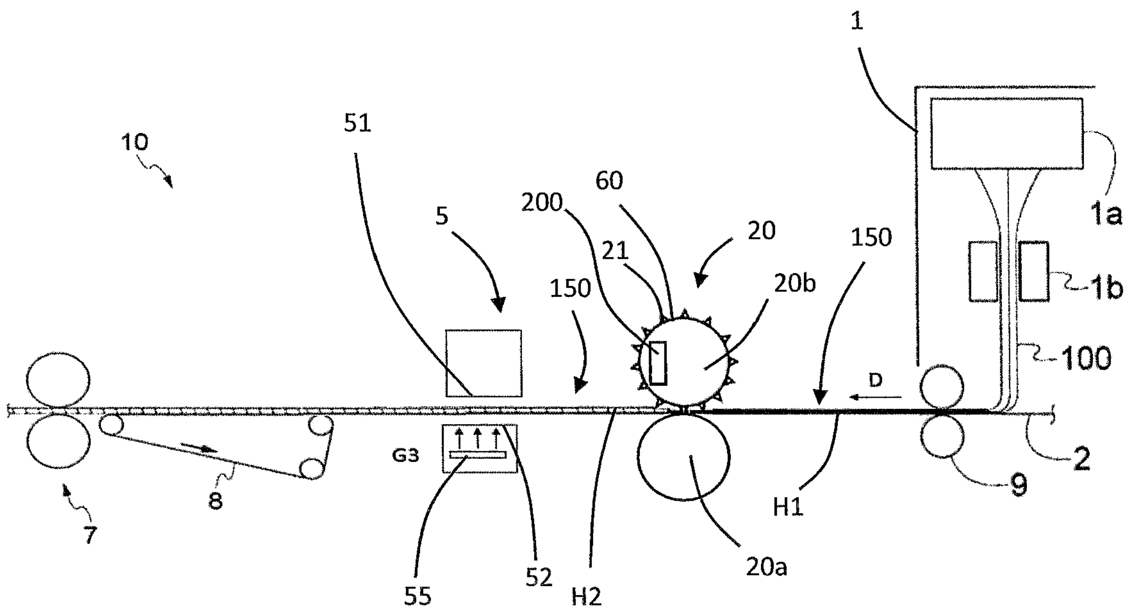
1
10
51
5
200
60
21
20
20b
150
150
1a
1b
100
D
G3
2
9
8
7
H1
20a
55
52
H2

Fig. 1

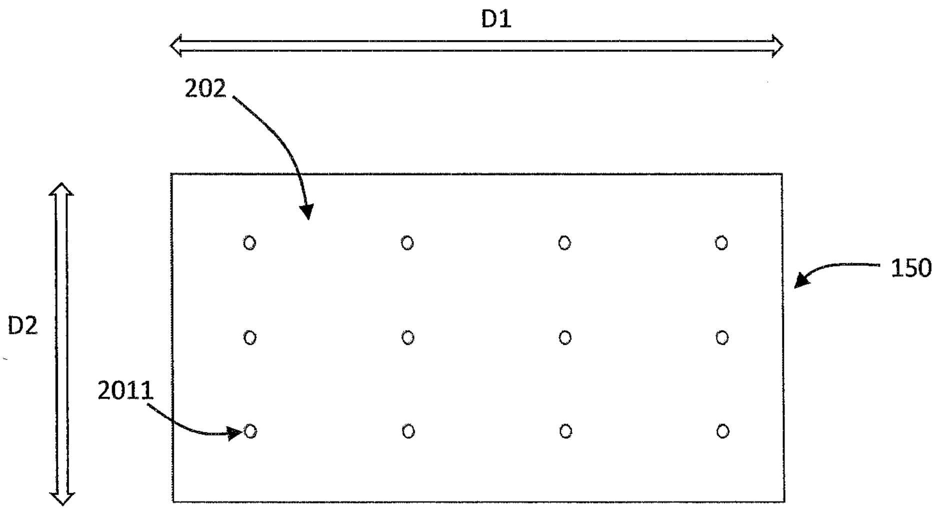
D1
202
150
D2
2011

Fig. 2

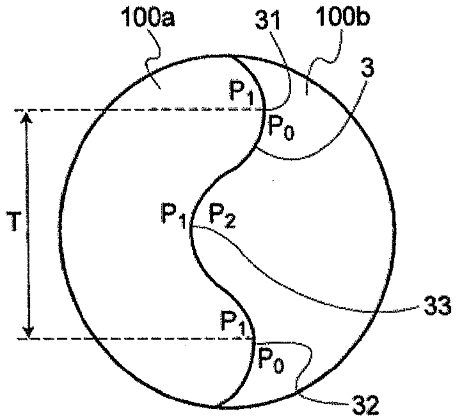

Fig. 3A

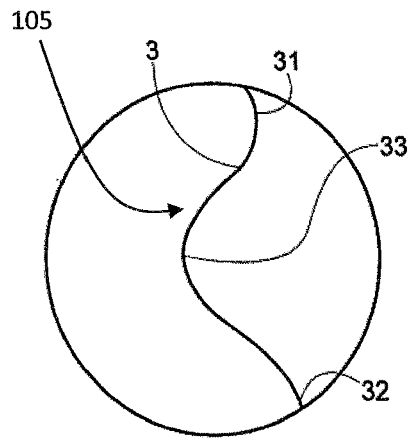

Fig. 3B

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EUROPEAN SEARCH REPORT

Application Number
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