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(54) PROCESS FOR PRODUCING AN ARTIFICIAL YARN AND A RELATED SYNTHETIC TURF MAT

(57) Process for producing an artificial yarn (3), comprising:
- providing a semi-finished yarn (1) made of a polymeric material (70), the semi-finished yarn (1) having a longitudinal direction (200);
- advancing the semi-finished yarn (1) along an advancement direction parallel to said longitudinal direction (200), during the advancing:
- heating the semi-finished yarn (1) above a predetermined temperature;
- transversally stretching the semi-finished yarn (1) along a transversal direction (201) perpendicular to the longitudinal direction (200);
- longitudinally stretching the semi-finished yarn (1) along the longitudinal direction (200);
- final cooling the semi-finished yarn (1) for obtaining the artificial yarn (3).

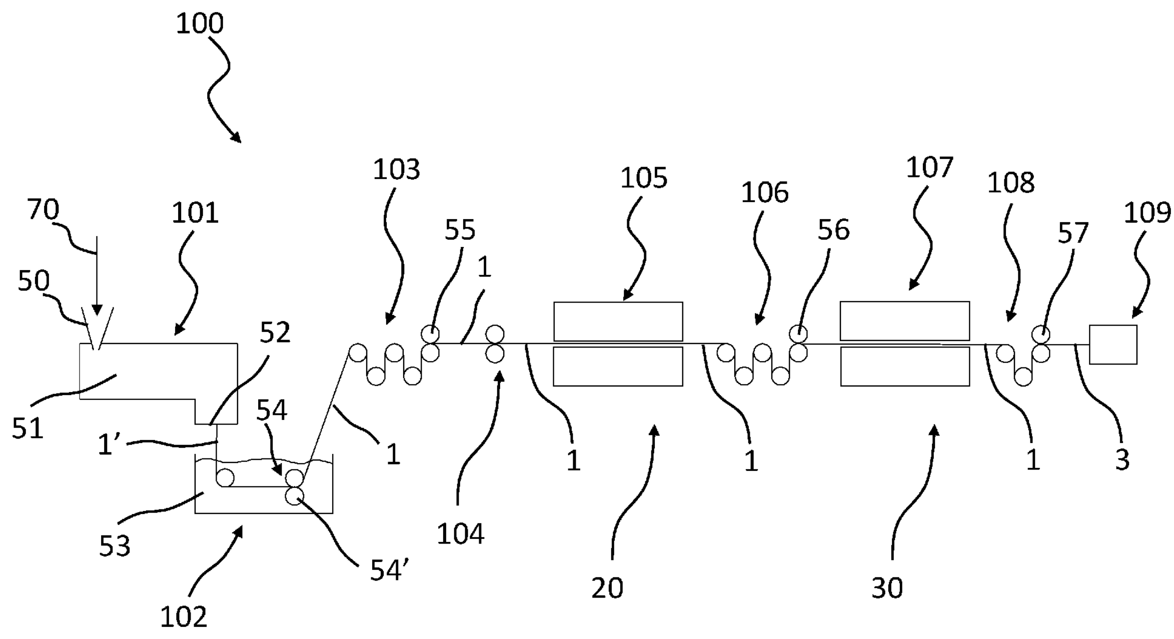

FIG. 1

Processed by Luminess, 75001 PARIS (FR)

Description

Technical field of the invention

[0001] The present invention relates to a process for producing an artificial yarn, for example suitable to be used in a synthetic turf mat, and to a process for producing a synthetic turf mat using such artificial yarn.

State of the art

[0002] A known process for producing artificial yarn comprises providing (e.g. by extrusion) a semi-finished yarn made of a polymeric material and advancing the semi-finished yarn along an advancement direction parallel to a longitudinal direction of the yarn, that is a main development direction of the semi-finished yarn and of the final artificial yarn. The known process comprises, while advancing the semi-finished yarn, heating the yarn above the glass transition temperature and stretching the semi-finished yarn along the longitudinal direction. In the end, the semi-finished yarn is cooled for obtaining the final artificial yarn.

[0003] Artificial yarn is typically used for making surfaces for sports use (e.g., soccer fields, football fields, rugby fields, baseball fields, etc.) and/or for decorative use (e.g., gardens), wherein a synthetic turf mat is laid above a rigid and compact substrate (e.g., in clay or asphalt) and typically a layer of infill material (e.g., in granules) is spread on the synthetic turf mat. The synthetic turf mat typically comprises at least a support ply and an artificial yarn fixed (e.g., tufted) to the support ply to realize artificial blades which simulate the natural grass filaments.

Summary of the invention

[0004] The term "yarn" indicates, e.g., a structurally continuous filiform element constituted by a single filament (i.e. a monofilament).

[0005] The term "longitudinal" or "longitudinally" is used to refer to a (local) main development direction of the artificial yarn (semi-finished or final) or blade, as the case may be.

[0006] Any reference to a "shape" of a yarn and to the related dimensions (e.g. major/minor dimension, width, thickness, etc) is meant to refer to the shape (or the contour of the shape) of the yarn, and its related dimensions, taken on a cross-section orthogonal to the longitudinal dimension. The term "width" refers to the major dimension of the shape and the term "thickness" refers to the dimension orthogonal to the major dimension.

[0007] "Flat shape" means that a major dimension of the shape of the yarn is at least two times, preferably at least three times, a dimension of the shape orthogonal to the major dimension.

[0008] "Glass transition temperature" (or Vicat softening temperature) means a (nominal) temperature value at which the polymeric material (typically a semi-crystalline polymer) passes from a glass state to an amorphous state when increasing its temperature. The glass transition temperature may exemplarily be measured by test method ASTM D1525. The Applicant has realized that the known processes for producing an artificial yarn, for example to be used in a synthetic turf mat, have some drawbacks and/or can be improved in one or more aspects.

[0009] For example, the Applicant has observed that the artificial yarn may have an undesirable transversal tensile strength, i.e., the tensile strength measured along a transversal direction perpendicular to the longitudinal direction. In case of low transversal tensile strength, the artificial yarn may not be able to efficiently withstand, over time, the transversal stresses to which it may be subjected during use (e.g., by way of bending, pressing, etc). This may happen for example when the yarn is used in a synthetic turf mat to make the artificial blades. The artificial blades can undergo a fast and/or high and/or undesired wear and/or damage and/or breakage (with a consequent loss of both performance and aesthetic properties). For example, the Applicant has observed that, due to transversal stresses, the artificial blades tend to split lengthwise (i.e., along the longitudinal direction) over time. The breakage of the yarn (or blades) may result in an undesirable production of polymeric microfibers which may disperse in the environment. The Applicant has also observed that the known processes for producing artificial yarn use PerFluorinated Alkylated Substances (PFAS) as a component in the polymeric material of the yarn. However, PFAS have recently raised great concern as regards their negative impact on the environment and/or on the human and other species health. It is therefore a general desire to reduce or avoid use of PFAS. However, the Applicant has discovered that reducing or eliminating PFAS as a component in the polymeric material may greatly reduce (up to 50%) the overall productivity of the production process (e.g. during the extrusion step) and/or may reduce the general strength of the yarn.

[0010] The Applicant has therefore faced the problems of producing an artificial yarn having high durability and/or high strength, for example resistance to stresses acting along the transversal direction of the yarn, by way of a process simple and/or cost effective and/or highly productive (e.g. in terms of length of yarn per time unit) and/or environment friendly (e.g. with no or limited use of PFAS and/or generation of microfibers from the final yarn during usage).

[0011] According to the Applicant, one or more of the above problems is solved by a process for producing an artificial yarn and a process for producing a synthetic turf mat according to the attached claims and/or having one or more of the following features.

[0012] According to an aspect the invention relates to a process for producing an artificial yarn, the process comprising:

- providing a semi-finished yarn made of a polymeric material, the semi-finished yarn having a longitudinal direction;
- advancing said semi-finished yarn along an advancement direction parallel to said longitudinal direction.

[0013] Preferably, during said advancing, the process comprises:

- heating said semi-finished yarn above a predetermined temperature;
- while above said predetermined temperature:
  - transversally stretching said semi-finished yarn along a transversal direction perpendicular to said longitudinal direction;
  - longitudinally stretching said semi-finished yarn along said longitudinal direction;
- final cooling said semi-finished yarn for obtaining said artificial yarn.

[0014] According to an aspect the invention relates to a process for producing a synthetic turf mat, the process comprising:

- providing a support ply;
- producing an artificial yarn according to the process of the present invention;
- fixing (e.g., by tufting) the artificial yarn to the support ply for making artificial blades.

[0015] Without intending to restrict to any theory, the Applicant believes that the transversal stretching of the semi-finished yarn along the transversal direction (at least partially) orients a not-negligible portion of the polymeric chains overall along the transversal direction. In this way, the artificial yarn is able to efficiently withstand over time the transversal stresses, in particular acting along the width of the yarn.

[0016] The Applicant believes that, in the starting semi-finished yarn, the polymeric chains of the polymeric material are overall randomly oriented and mutually weakly bonded by way of intermolecular bonds (e.g., Van der Waals bonds) formed between the molecules of adjacent polymeric chains.

[0017] The Applicant has realized that, in the prior art process, the stretching of the semi-finished yarn made of polymeric material solely along the longitudinal direction causes an orientation of most of (or substantially all) the polymeric chains of the polymeric material overall along the longitudinal direction of the yarn. The prior art artificial yarn with such internal structure of the polymeric chains may have an undesirable transversal tensile strength as described above.

[0018] On the contrary, the transversal stretching at a suitable temperature according to the present invention breaks (at least some of) the weak intermolecular bonds and creates reactive points (e.g., electrically charged molecules) on the polymeric chains. Each reactive point, after the (at least partial) reorientation of the not-negligible portion of the polymeric chains overall along the transversal direction, tends to form a new bond with a respective reactive point of another nearby polymeric chain. The same principle applies in connection to the longitudinal stretching, resulting in a (at least partial) reorientation of a not-negligible portion of the polymeric chains overall along the longitudinal direction. The process of orientation is physical (e.g. by van der Waals force) and therefore reversible, making yarn recycling possible. On the contrary, a chemically crossed orientated yarn could not be recycled.

[0019] The combination of the longitudinal and the transversal stretching results in a final internal structure of the semi-finished yarn wherein the polymeric chains are (at least in part) overall oriented not only along the longitudinal direction, but also along the transversal direction, this internal structure being maintained in the final artificial yarn (e.g. after the stabilization provided, at least in part, by the cooling).

[0020] The high strength of the artificial yarn obtained in this way results in a reduced amount of microfibers released in the environment over time, during the use of the yarn, e.g, as artificial grass blades.

[0021] In particular, the artificial yarn produced according to the present invention can efficiently withstand the stresses along the transversal direction. This makes the artificial yarn of the present invention particularly suitable to be used in a synthetic turf mat since the transversal direction, together with the longitudinal direction, is the main direction along which the artificial yarn is stressed during use in the synthetic turf mat. Therefore, the artificial yarn has a suitable durability and/or resistance for being used to make artificial blades of a synthetic turf mat. However, the artificial yarn of the present invention may be advantageously used in any application requiring the withstanding of stresses acting along the transversal direction, for example for making decorative tapes, ribbons, webbings (e.g., for lawn chairs), bristles (e.g., for toothbrushes), sewing thread (e.g., for home furnishings, industrial textiles, apparel, and/or floor coverings), or in the field of packaging or tire reinforcement.

[0022] The Applicant has also surprisingly found that the process of the present invention allows to reduce or avoid the content of PFAS in the polymeric material of the yarn, with little or no drawbacks in the overall productivity of the process and/or in the strength of the final yarn.

[0023] The present invention in one or more of the aforesaid aspects can have one or more of the following preferred features.

[0024] Preferably providing said semi-finished yarn comprises:

- providing said polymeric material;
- melting said polymeric material, more preferably in

an (screw) extruder;

- extruding said (molten) polymeric material (through an extrusion head) for obtaining an extruded semi-finished yarn.

[0025] The Applicant believes that the extrusion allows to provide suitable production volumes while obtaining a good reliability and/or consistency of the mass and/or dimensional parameters of the semi-finished yarn in output from the extruder.

[0026] Preferably said polymeric material comprises (e.g. as a main component, e.g. with a weight content of at least 60% or 70% or 80%) polypropylene (PP) or polyethylene (PE). Preferably said polymeric material comprises low-density polyethylene (LDPE), more preferably linear low-density polyethylene (LLDPE). The Applicant has observed that these materials, in particular the LDPE and LLDPE, are particularly suitable to be used for making the artificial yarn according to the present invention in order to achieve the described effects.

[0027] Preferably a weight content of PerFluorinated Alkylated Substances (PFAS) in said polymeric material is less than or equal to 3%, more preferably less than or equal to 1%, even more preferably substantially zero (e.g. less than 0,01 %).

[0028] Preferably no PFAS is added to said polymeric material during melting (e.g. extruding).

[0029] Preferably said semi-finished yarn before said transversally stretching (more preferably before said longitudinally stretching and said heating, e.g., said provided or extruded semi-finished yarn), has a smooth shape (i.e. with no angles). In this way the extrusion process is facilitated, improving productivity and/or extending lifetime of the extrusion head.

[0030] Preferably the shape of said semi-finished yarn before said transversally stretching has a non-flat shape, i.e. with a major dimension less than two times the minor dimension. Preferably the major dimension is greater than or equal to 0.3 mm, or 0.5 mm, and/or less than or equal to 4 mm or 3 mm. In embodiments, said shape is (substantially) round or oval. The Applicant noted that in known prior art processes for producing an artificial yarn, the semi-finished yarn is extruded or provided already in a rectangular, flat shape (e.g. by way of extrusion head with rectangular openings). The Applicant believes that the non-flat shape of the present invention facilitates subjecting the semi-finished yarn to the transversal stretching according to the invention. In addition, the smooth and/or non-flat shape may allow an easier drying of the extruded semi-finished yarn following the bath. This contributes to the overall efficiency of the process since the low or null quantity of water on the semi-finished yarn favours the subsequent heating, avoiding heat absorption by water evaporation.

[0031] Preferably said providing said semi-finished yarn comprises (e.g. after said extruding) quenching said extruded semi-finished yarn, more preferably at a temperature below a glass transition temperature of the polymeric material, e.g. below 50°C or 40°C and/or above 15°C, for obtaining said semi-finished yarn. In this way it is possible to fix the shape of the extruded semi-finished yarn.

[0032] Preferably said quenching said extruded semi-finished yarn comprises soaking said extruded semi-finished yarn in a water bath, preferably at a temperature of the water bath less than or equal to 40°C, more preferably less than or equal to 35°C (and preferably drying said semi-finished yarn after exit from said water bath). The relatively high thermal conductivity of water (e.g., with respect to air) allows a rapid and/or low-cost cooling of the extruded semi-finished yarn. This contributes to the overall efficiency of the process. Moreover, the water bath is a cheap and/or low-energy consuming device.

[0033] Preferably said heating said semi-finished yarn is after said quenching.

[0034] Preferably said heating comprises advancing the yarn along a first roll stage comprising rollers at a stabilized temperature above said predetermined temperature.

[0035] Preferably said predetermined temperature is greater than or equal to 70°C, or 80°C, or 90°C. Preferably, said predetermined temperature is a glass transition temperature of said polymeric material. The Applicant has observed that by keeping the temperature above the glass transition temperature of the polymeric material it is possible to favour the breaking of the weak intermolecular bonds and therefore the reorientation of the polymeric chains in the stretching direction(s).

[0036] Preferably said artificial yarn, e.g. the final artificial yarn, has a flat shape, typically constant moving along the longitudinal direction.

[0037] Preferably said transversally stretching gives to said semi-finished yarn a respective flat shape. In this way, with a single production step, it is possible to provide a flat shape to the artificial yarn and the above-described transversal orientation of the polymeric chains. Preferably a major dimension (or width) of said flat shape (of the artificial yarn and/or of the semi-finished yarn after transversally stretching) is along said transversal direction (i.e. along the direction of the transversal stretching).

[0038] Preferably said flat shape has two rectilinear opposite sides (more preferably mutually parallel) developing along the transversal direction and two curvilinear opposite sides (with inward concavity) connecting the two rectilinear sides.

[0039] In one or more embodiments of the invention, the shape of the final artificial yarn may be non-flat, or flat with a shape different from the above one, such as diamond shape, oval or elliptical shape, C- or V-shape, or any other shape known in the art.

[0040] In one or more embodiments, the process may comprise a re-shaping step (e.g. at or above said predetermined temperature) other than the transversal stretching and/or the longitudinal stretching.

[0041] Preferably a ratio of a width of the semi-finished yarn after and before said transversally stretching is greater than or equal to 2, more preferably greater than or equal to 2.5. The Applicant has verified that such ratio values are suitable to provide the desired orientation effects of the present invention.

[0042] Preferably said transversally stretching comprises (or consist in) calendering said semi-finished yarn (e.g., by means of a calender). In this way the transversal stretching is efficiently and/or simply performed.

[0043] Preferably said calender comprises two rollers (more preferably two and only two rollers) spaced apart from each other (i.e., with a gap between the rollers), more preferably both motorized. Preferably the rollers have cylindrical shape. Preferably said two rollers are vertically superimposed (or aligned) to each other (so the advancement direction of the semi-finished yarn is horizontal during calendering). Preferably respective rotation axis of said two rollers are parallel to each other and more preferably parallel to said transversal direction. In this way the calender has a simple and rational structure and/or can efficiently contribute to impart the transversal orientation to the polymeric chains.

[0044] Preferably a gap between said two rollers is less than or equal to 1 mm, more preferably less than or equal to 0.8 mm, even more preferably less than or equal to 0.5 mm, and/or greater than or equal to 0.05 mm, more preferably greater than or equal to 0.1 mm. Preferably the thickness of the (final) artificial yarn is (substantially) equal to said gap of the calender. In this way the artificial yarn has the desired thickness.

[0045] Preferably said transversally stretching is (completely) carried out before at least part (more preferably a substantial part) of said longitudinally stretching. In the invention, a certain (small) amount of longitudinal stretching may happen before and/or contemporaneously to the transversal stretching. The Applicant has observed that it is more efficient and/or easier and/or more reliable to impart the transversal orientation to the polymeric chains before most of the longitudinal stretching (e.g. to the (quenched) polymeric material after extrusion), wherein the polymeric chains are still overall randomly oriented.

[0046] Preferably said longitudinally stretching comprises advancing said semi-finished yarn along a first stretch, wherein a ratio of an advancement speed at an end of said first stretch and at a start of said first stretch is higher than 2, more preferably higher than 3. Preferably said start of said first stretch is immediately after said transversally stretching (at said calender) and said end of said first stretch is at a second roll stage. In this way it is possible to provide the desired longitudinal orientation while reducing the overall duration of the process making it compatible with the industrial needs.

[0047] Preferably said heating comprises keeping said rollers of the calender at a set temperature above said predetermined temperature and/or passing the yarn through a first (air) oven along said first stretch.

[0048] Preferably the process comprises intermediate cooling the semi-finished yarn after said longitudinally stretching (e.g. at the end of the first stretch), e.g. by keeping said rollers of the second roll stage below said predetermined temperature.

[0049] Preferably a width of the semi-finished yarn after said longitudinally stretching is smaller than a width of said semi-finished yarn immediately after the transversal stretching, e.g. at the start of the first stretch (i.e. before a substantial part of the longitudinal stretching). Preferably a thickness of the semi-finished yarn after said longitudinally stretching (and of the final artificial yarn) is (substantially) equal to a thickness of the semi-finished yarn immediately after said transversally stretching (and before a substantial part of the longitudinal stretching). In other words, the longitudinal stretching after the transversal stretching causes a shrinkage of the artificial yarn in the transversal direction, while the thickness of the yarn remains substantially unaltered during the steps subsequent to the transversal stretching, including the possible subsequent shrinking.

[0050] Preferably, subsequently to said transversally stretching and said longitudinally stretching (e.g. after said intermediate cooling) and before said final cooling, the process comprises further heating said semi-finished yarn. Preferably said further heating brings said semi-finished yarn at a respective temperature greater than a maximum temperature of said semi-finished yarn reached during said heating, e.g. at a respective temperature greater than 90°C or 100°C or 110°C. Preferably, the process comprises, during said further heating, longitudinally shrinking the semi-finished yarn (e.g., the mass per unit of length at the start of the shrinking is lower than the mass per unit of length at the end of the shrinking). Preferably said longitudinally shrinking comprises advancing said semi-finished yarn along a second stretch, wherein an advancement speed at an end of said second stretch is lower (e.g. by 10%) than at a start of said second stretch. Preferably said start of said second stretch is at said end of said first stretch (e.g. at said second roll stage) and said end of said second stretch is at a third roll stage. Preferably said further heating comprises passing the semi-finished yarn through a second (air) oven along said second stretch. In this way (together with the subsequent final cooling of the semi-finished yarn) it is possible to anneal the yarn (i.e. to release the internal stresses) and stabilize the internal structure of the polymeric material, fixating the orientation of the polymeric chains. The Applicant has realized that, in absence of such further heating and shrinking, the artificial yarn could unpredictably deform (e.g., shrink) during storage, thus making the artificial yarn unsuitable for use.

[0051] Preferably said final cooling said semi-finished yarn brings said semi-finished yarn at a temperature less than or equal to 40°C, more preferably less than or equal to 35°C, and/or greater than or equal to 15°C. Preferably said final cooling said semi-finished yarn comprises advancing said semi-finished yarn (in room-temperature air) along a (e.g. said third) roll stage comprising rollers at a stabilized temperature less than or equal to 40°C, more preferably less than or equal to 35°C. In this way the semi-finished yarn is efficiently cooled down to obtain the annealed final artificial yarn.

[0052] Preferably, during said transversally stretching and/or said longitudinally stretching (more preferably during all the steps following said providing the semi-finished yarn, e.g., by extrusion), said semi-finished yarn is kept at a temperature less than a melting temperature of said polymeric material (e.g., measured by differential scanning calorimetry, or DSC, thermo-analytical technique). In this way a complete loss of structural stability of the semi-finished yarn is prevented.

[0053] Preferably said artificial yarn has a percentage of polymeric chains overall oriented along said transversal direction greater than or equal to 5%, more preferably 10%, and/or lower than or equal to 50%, more preferably 40%, of the overall length of the polymeric chains. In this way the final artificial yarn can efficiently withstand the transversal stresses, for example those typically present in a synthetic turf mat, and also the longitudinal stresses (i.e., does not break).

[0054] Preferably said artificial yarn has a mass per unit of length greater than or equal to 500 dtex, more preferably greater than or equal to 1000 dtex, even more preferably greater than or equal to 1500 dtex, and/or less than or equal 4000 dtex, more preferably less than or equal to 3500 dtex, even more preferably less than or equal to 3000 dtex. The Applicant has observed that a mass per unit of length within the above ranges is particularly suitable for making the artificial blades for a synthetic turf mat.

[0055] Preferably a ratio between a mass per unit of length of said semi-finished yarn before both said transversally and longitudinally stretching and said mass per unit of length of said artificial yarn is greater than or equal 2, more preferably greater than or equal to 2.5, even more preferably greater than or equal to 3, and/or less than or equal 6, more preferably less than or equal to 5.5, even more preferably less than or equal to 5. In this way it is possible to provide a good compromise between the productivity of the process in terms of length of artificial yarn per time unit and avoidance of the splitting problem along the longitudinal direction.

Brief description of the drawings

[0056]

Figure 1 schematically and partially shows an example of plant for carrying out a process for producing an artificial yarn according to the present invention;

Figure 2a schematically and partially shows a calendering step of the process according to the present invention;

Figures 2b-c schematically and partially shows a semi-finished yarn respectively before and after the calendering step;

Figure 3 schematically and partially show a plan view of an example of internal structure of the polymeric chains in an artificial yarn produced respectively with a process according to the present invention (left and top-right) and a process according to the prior art (left and bottom-right);

Figures 4a-b schematically and partially show respectively a transversally stretched semi-finished yarn and a final artificial yarn.

Detailed description of some embodiments of the invention

[0057] The features and the advantages of the present invention will be further clarified by the following detailed description of some embodiments, presented by way of non-limiting examples of the present invention, with reference to the attached figures. The figures are shown not in scale, and only for illustrative purpose.

[0058] With reference to figure 1, reference number 100 indicates a plant for carrying out a process for producing an artificial yarn 3 according to the present invention. The components/devices of the plant 100 are described from left to right of figure 1, this oriented direction corresponding also to a temporal sequence of the process steps. Exemplarily the plant 100 comprises at least one extruder 101 (only schematically shown) comprising an inlet mouth 50 (or, not shown, a plurality of inlet mouths), a mixing chamber 51 and an extrusion head 52 at an end distal from the inlet mouth 50. For example, the extruder 101 is a screw extruder, e.g., a single-screw or a double-screw or a ring or a planetary extruder, with the screw(s) housed in the mixing chamber 51.

[0059] The extruder 101 further comprises heating means (not shown and for example of known type) acting on the mixing chamber 51.

[0060] Exemplarily the extrusion head 52 comprises a plurality of openings (not shown), preferably having a smooth and non-flat cross-sectional shape, such as rounded or oval. Alternatively, the openings may have a flat shape, e.g., rectangular or oval, provided the aspect ratio allows the subsequent transversal stretching to the desired extent.

[0061] Exemplarily, (e.g., directly) downstream the extruder 101, the plant 100 comprises a water bath 102 comprising a tank 53 filled with water. Exemplarily the water bath 102 comprises a thermo-conditioning device (not shown) which allows to maintain the water inside the tank 53 at a set temperature.

[0062] Exemplarily the water bath 102 comprises a transport unit 54 (only schematically shown) housed in the tank 53 for advancing the yarn through the tank 53 (e.g., by way of a plurality of rollers). Exemplarily the transport unit 54 comprises at least one motorized traction roller 54' (only schematically illustrated), which contributes to advancing the yarn by imparting a respective set advancement speed.

[0063] Exemplarily, (e.g., directly) downstream the water bath 102, the plant 100 comprises a first roll stage 103 comprising a sequence of rollers having a respective rotation axis which are for example parallel to each other. Exemplarily the first roll stage 103 comprises at least one respective motorized traction roller 55 which, aided by an idle counter roller, contributes to advancing the yarn by imparting a respective set advancement speed. Exemplarily the first roll stage 103 comprises a respective thermo-conditioning device (not shown) which allows to maintain the rollers (e.g., at least a respective outer surface of the rollers) at a set temperature.

[0064] Exemplarily, (e.g., directly) downstream the first roll stage 103, the plant 100 comprises a calender 104 exemplarily consisting of two (both motorized) cylindrical rollers 41 and 42 (see figure 2a) rotatable about a respective rotation axis (typically parallel to each other) at a set rotation speed. Typically, the two rollers 41 and 42 rotate in opposite directions (e.g., the upper one counterclockwise and the lower one clockwise). Exemplarily the two rollers 41 and 42 are vertically superimposed and exemplarily spaced apart to form a gap h (figure 2a) for example equal to about 0.3 mm between the two rollers 41 and 42. Exemplarily the calender 104 comprises a respective thermo-conditioning device (not shown) which allows to maintain the two rollers (e.g., at least a respective outer surface of the rollers) at a fixed set temperature.

[0065] Exemplarily, (e.g., directly) downstream the calender 104, the plant 100 comprises a first stretch 20 starting at the calender 104 and ending at a second roll stage 106. Exemplarily the second roll stage 106 is structurally (possibly except for the number of rollers) and operationally similar or equal to the first roll stage 103, e.g., it comprises a sequence of respective rollers (including at least one respective traction roller 56) and a respective thermo-conditioning device (not shown).

[0066] The plant comprises, along the first stretch 20, a first oven 105, for example a hot-air oven which comprises one or more heating elements and one or more fans. The combination of heating elements and fans is able to create a movement of hot air inside the oven (e.g., heating through convention). The Applicant has realized that a hot-air oven is highly efficient and/or limit cleaning problems.

[0067] Alternatively, other types of ovens (e.g., hot-water ovens or infrared ovens) can be used for example as known in the art.

[0068] The first oven 105 may be a single-bodied oven (as exemplarily shown in figure 1) or (not shown) it may comprise a plurality of single-bodied sub-units distributed in sequence with interposed roll stages, e.g., two single-bodied ovens.

[0069] Exemplarily, (e.g., directly) downstream the first stretch 20, the plant 100 comprises a second stretch 30 starting at the second roll stage 106 (at the traction roller 56) and ending at a third roll stage 108. Exemplarily the third roll stage 108 comprises a sequence of respective rollers (including at least one respective traction roller 57) and a respective thermo-conditioning device (not shown). The third roll stage 108 is structurally (possibly except for the number of rollers) and operationally similar to the first 103 and the second roll stage 106.

[0070] The plant comprises, along the second stretch 30, a second oven 107. For example, the second oven 107 is a further hot-air oven similar or substantially identical to the first oven 105. Alternatively, other types of ovens (e.g., hot-water or IR ovens) can be used for example as known in the art.

[0071] Finally, (e.g., directly) downstream the third roll stage 108, the plant 100 comprises a storage station 109 (e.g., comprising motorized reels) for collecting and storing the final artificial yarn 3.

[0072] In the following an example of a process for producing the artificial yarn 3 will be described, such process being implementable with the above-described plant 100.

[0073] The reference number 1 is used to indicate the semi-finished yarn in any phase of the process (except for the extruded semi-finished yarn 1'), even though the semi-finished yarn typically varies its shape, temperature, dimensions and/or internal structure along the process.

[0074] The process comprises providing a polymeric material 70, for example a mixture mainly comprising LLDPE, for example in the form of granules, possibly together with process-aiding additives, dies, etc. Exemplarily the polymeric material has a glass transition temperature of about 85°C (in other embodiments up to 120°C) and a melting temperature of about 120°C (in other embodiments in the range 100-135°C).

[0075] The polymeric material 70 is for example fed to the extruder 101 through the inlet mouth 50 and processed in the mixing chamber 51. Preferably, no PFAS is added into the extruder 101. The processing in the mixing chamber 51 exemplarily comprises melting the polymeric material 70 (e.g., bringing the polymeric material above its melting temperature) while moving it from the inlet mouth 50 towards the extrusion head 52. For example, the polymeric material 70 inside the mixing chamber 51 is brought at a temperature comprised in the range 180-200°C.

[0076] The polymeric material 70 is then extruded from the openings of the extrusion head 52 to obtain extruded semi-finished yarns 1', one from each opening of the extrusion head 52, thus forming a plurality of parallel extruded semi-finished yarns 1'. All the extruded semi-finished yarns are then advanced in parallel and subjected to the following process steps contemporaneously. For easiness of explanation, in the following and in the figures, reference is made to only one semi-finished yarn 1', 1 and respective finished yarn 3. The invention also contemplates the processing of one single yarn.

[0077] The extruded semi-finished yarn 1' has a longitudinal direction 200, coinciding with a main development direction of the extruded semi-finished yarn 1'.

[0078] The extruded semi-finished yarn 1' has exemplarily a mass per unit length equal to about 8000 dtex.

[0079] Exemplarily, the extruded semi-finished yarn 1' has round shape with diameter d for example equal to about 1 mm. The round shape of the extruded semi-finished yarn 1' is typically determined by the shape of the openings of the extrusion head 52. For example, in case of openings with rectangular or oval shape, the extruded semi-finished yarn 1' has a corresponding rectangular or oval shape.

[0080] After the extrusion, the extruded semi-finished yarn 1' is advanced along a (local) advancement direction parallel to the (local) longitudinal direction 200 (the advancement of the yarn generally goes from left to right in figure 1).

[0081] The extruded semi-finished yarn 1' exemplarily enters the water bath 102, moving from the entry of the water bath 102 to the exit of the water bath 102 under the traction provided by (at least) the traction roller 54'. The traction rollers 54', 55, 56 and 57 and the calender 104 preferably allow an advancement of the yarn at respective set speed with no or negligible sliding on the outer surface of the rollers.

[0082] Exemplarily the traction roller 54' impart an advancement speed (expressed as meters of yarn per minute) equal to about 25 m/min.

[0083] The water in the water bath 102 is set (by the respective thermo-conditioning device) at a temperature for example equal to about 26°C which allows a quenching of the extruded semi-finished yarn 1'. For example, the extruded semi-finished yarn 1', at the exit of the water bath 102, is substantially at the same temperature of the water.

[0084] The quenching of the extruded semi-finished yarn 1' allows obtaining a wet semi-finished yarn 1 which is subsequently dried.

[0085] In an alternative not shown embodiment, the above-described extrusion, quenching and drying are not present and an already prepared semi-finished yarn is directly provided, e,g, at input to the first roll stage 103. For example, the semi-finished yarn can be provided by appropriate cutting of strips from a ribbon or ply made of the polymeric material and unwound from a reel (in this case the semi-finished yarn would typically not have a non-flat shape). Alternatively, the semi-finished yarn can be prepared in a previous industrial step and wound on a reel, which is directly provided at the beginning of the process. However, the extrusion as described above allows a continuous process.

[0086] The wet semi-finished yarn 1 is then further advanced by the traction provided by (at least) the traction roller 55 of the first roll stage 103. For example, the traction roller 55 is set at an advancement speed substantially equal to the respective advancement speed of the traction roller 54' (e.g., equal to about 25 m/min). Advantageously in this way the yarn substantially does not undergo any longitudinal stretching advancing from the bath 102 to the first roll stage 103.

[0087] Subsequently, the (wet) semi-finished yarn 1 is heated e.g., by way of the rollers of the first roll stage 103 maintained at a set temperature (by the respective thermo-conditioning device) greater than the glass transition temperature of the polymeric material and lower than the melting temperature of the polymeric material, for example at about 94°C. This also favours the drying of the wet semi-finished yarn 1. At the end of the first roll stage 103, the semi-finished yarn 1 is at a temperature for example equal to about 90°C.

[0088] The heated semi-finished yarn 1 is then advanced towards the calender 104. The rollers 41 and 42 of the calender 104 provides a traction on the semi-finished yarn 1, with the rollers 41 and 42 imparting an advancement speed for example equal to about 30 m/min. In the calender, the semi-finished yarn 1 undergoes a transversal stretching, i.e., a stretching along a transversal direction 201 perpendicular to the longitudinal direction 200 (and to the drawing plane of fig. 1), thus obtaining a transversally stretched semi-finished yarn 1.

[0089] As schematically shown in figures 2a-2c, the passage of the semi-finished yarn 1 in the calender 104 causes a (possibly further) flattening of the semi-finished yarn 1, which assumes a flat shape.

[0090] Exemplarily, the transversally stretched semi-finished yarn 1 (immediately after calendering) has a width W (along the transversal direction 201) equal to about 3 mm and a thickness s (along a direction 202 perpendicular to the transversal direction 201) equal to about 0.3 mm, the thickness s being typically defined by the gap h of the calender 104. The aspect ratio is exemplarily equal to about 10 and the ratio of the width of the semi-finished yarn after (W) and before (d) transversally stretching is equal to about 3. Advantageously the rollers 41 and 42 of the calender are thermo-conditioned (through the respective thermo-conditioning device) at a temperature greater than the glass transition temperature of the polymeric material and lower than the melting temperature of the polymeric material, for example at a temperature equal to about 94°C. Therefore, at the exit of the calender 94, the transversally stretched semi-finished yarn 1 is exemplarily maintained at a temperature equal to about 90°C.

[0091] It is noted that a partial longitudinal stretching of the semi-finished yarn 1 may occur during the advancement of the semi-finished yarn 1 from the first roll stage 103 up to the exit of the calender 104. Such partial longitudinal stretching may be given by the difference in the advancement speed provided by the traction roller 55 and the rollers 41 and 42 of the calender 104, and/or by the squeezing imparted by the calender 104. It is noted that, in steady-state conditions, since the flux of material across any cross-section of the yarn, i.e., the mass of yarn crossing the cross-section in the time unit, is substantially the same along the whole plant 100, and since the flux of material is given by the product of the mass per unit of length and the advancement speed of the yarn, the mass per unit of length and the advancement speed are inversely proportional to each other. This means that when for example the advancement speed increases along the plant 100, a decrease of the mass per unit of length (i.e., a decrease of the cross-sectional area) of the semi-finished yarn occurs, which is due to a longitudinal stretch.

[0092] After the calendering step, the process comprises advancing the transversally stretched semi-finished yarn 1 along the first stretch 20 including the first oven 105, by means of the second roll stage 106, e.g. of (at least) the traction roller 56 set at an advancement speed of about 115 m/min. The higher traction speed provided by the traction roller 56 of the second roll stage 106 with respect to the calender 104 causes a longitudinal stretching of the transversally stretched, and heated, semi-finished yarn 1, thus obtaining a transversally and longitudinally stretched semi-finished yarn 1.

[0093] The first oven 105 is exemplarily set so that the hot-air circulating in the oven is at a temperature above the glass transition temperature of the polymeric material and lower than the melting temperature of the polymeric material for heating the transversally stretched semi-finished yarn 1. For example, the hot-air is at a temperature equal to about 106°C and, at the end of the first oven 106 (after few seconds of travelling time, e.g., 5 s), the temperature of the transversally and (almost completely) longitudinally stretched semi-finished yarn 1 is equal to about 100°C.

[0094] Exemplarily, the rollers of the second roll stage 106 are set (by the respective thermo-conditioning device) at a temperature equal to about 70°C. In this way the transversally and longitudinally stretched semi-finished yarn 1 is intermediate cooled while passing through the second roll stage 106 and it is prepared for the subsequent annealing.

[0095] The transversally and longitudinally stretched semi-finished yarn 1 is then advanced along the second stretch 30 comprising the second oven 107 by means of the third roll stage 108, e,g, by means of (at least) the traction roller 57, for example set at an advancement speed equal to about 100 m/min.

[0096] The second oven 107 is exemplarily set so that the hot-air circulating in the oven is at a temperature greater than the melting temperature of the polymeric material, for example a temperature equal to 138°C. For example, the crossing along the second oven 107 lasts very few seconds, e.g., 2.5 seconds, to further heating the transversally and longitudinally stretched semi-finished yarn 1 while avoiding that the yarn reaches its melting temperature in the second oven. For example, at the exit of the second oven 107, the transversally and longitudinally stretched semi-finished yarn 1 is for example at a temperature equal to about 115°C (slightly lower than the melting temperature).

[0097] During the advancement along the second stretch 30, the transversally and longitudinally stretched semi-finished yarn 1 advantageously undergoes a (more preferably purely) longitudinal shrinking. For example, the overall longitudinal shrinking of the transversally and longitudinally stretched semi-finished yarn 1 along the second stretch 30 is equal to about 7-8%.

[0098] Exemplarily the rollers of the third roll stage 108 are thermo-conditioned at a temperature for example equal to about 30°C, in order to finally cool the semi-finished yarn 1, thus obtaining the final artificial yarn 3. The shrinking of the heated transversally and longitudinally stretched semi-finished yarn 1 allows to relax the internal stresses provided by the transversal and longitudinal stretching, thus favouring, after final cooling, the stabilization of the desired shape and internal structure of the yarn 1.

[0099] As schematically shown in figure 4a-b, the final artificial yarn 3 (figure 4b) exemplarily has substantially the same thickness s of the semi-finished yarn 1 immediately after the transversal stretching (figure 4a) - e.g., the semi-finished yarn 1 at the exit from the calender 104 - and a width w which is lower than the width W of the semi-finished yarn 1 immediately after the transversal stretching. For example, the width w of the artificial yarn 3 is equal to about 1 mm. In other words, the yarn is subject to a transversal shrinkage after the transversal stretching, mainly due to the longitudinal stretching.

[0100] Exemplarily the artificial yarn 3 has a mass per unit of length equal to about 2000 dtex.

[0101] Exemplarily the artificial yarn 3 has a percentage of polymeric chains oriented along the transversal direction 201 equal to about 15% of the overall length of the polymeric chains. With reference to figure 3, it is schematically shown (left side) the internal structure of the semi-finished yarn 1 before any stretching (i.e., with the overall random orientation of the polymeric chains), e.g., immediately after extrusion and quenching in the water bath, and (right side) the internal structure of an artificial yarn 3 produced by the process according to the present invention (top-right) and an artificial yarn 300 produced according to a prior art process (bottom-right). As can be seen, the artificial yarn 3 produced according to the present invention has a non-negligible portion of the polymeric chains orientated along the transversal direction 201, while in the yarn 300 obtained by the prior art process substantially all the polymeric chains are overall oriented along the longitudinal direction 200.

[0102] In an embodiment, not shown, the process may comprise a step of shaping the yarn differently from the substantially rectangular shape described above (fig 4b), e.g. a diamond shape, a convex lens shape, an oval shape, a C- or V-shape, or any other known shape. Such shape may be performed during or after the step of transversal (and/or longitudinal) stretching, e.g. by way of a suitably shaped (further) calender, e.g. when the yarn is above the glass transition temperature.

Claims

1. Process for producing an artificial yarn (3), the process comprising:

- providing a semi-finished yarn (1) made of a polymeric material (70), the semi-finished yarn (1) having a longitudinal direction (200);
- advancing said semi-finished yarn (1) along an advancement direction parallel to said longitudinal direction (200),

wherein, during said advancing, the process comprises:

- heating said semi-finished yarn (1) above a predetermined temperature;
- while above said predetermined temperature:

  - transversally stretching said semi-finished yarn (1) along a transversal direction (201) perpendicular to said longitudinal direction (200);
  - longitudinally stretching said semi-finished yarn (1) along said longitudinal direction (200);

- final cooling said semi-finished yarn (1) for obtaining said artificial yarn (3).

2. Process according to claim 1, wherein providing said semi-finished yarn (1) comprises:

- providing said polymeric material (70);
- melting said polymeric material (70) in an extruder (101);
- extruding said polymeric material (70) for obtaining an extruded semi-finished yarn (1');
- after said extruding, quenching said extruded semi-finished yarn (1') for obtaining said semi-finished yarn (1),

wherein said quenching said extruded semi-finished yarn (1') comprises soaking said extruded semi-finished yarn (1') in a water bath (102) at a temperature of the water bath (102) less than or equal to 40°C.

3. Process according to anyone of the preceding claims, wherein said polymeric material (70) comprises polypropylene (PP) or linear low-density polyethylene (LLDPE) and a weight content of PerFluorinated Alkylated Substances (PFAS) equal to substantially zero.

4. Process according to anyone of the preceding claims, wherein said semi-finished yarn (1') before said transversally stretching has a smooth and non-flat shape, wherein said transversally stretching gives to said semi-finished yarn (1) a respective flat shape, wherein said artificial yarn (3) has a flat shape, a major dimension of said flat shape being along said transversal direction (201), and wherein said flat shape has two rectilinear opposite sides developing along the transversal direction (201) and two curvilinear opposite sides connecting the two rectilinear sides.

5. Process according to anyone of the preceding claims, wherein a ratio of a width of the semi-finished yarn after (W) and before (d) said transversally stretching is greater than or equal to 2.

6. Process according to anyone of the preceding claims, wherein said transversally stretching comprises calendering said semi-finished yarn (1) by means of a calender (104) comprising two motorized cylindrical rollers (41, 42) spaced apart from each other, wherein said two rollers (41, 42) are vertically superimposed to each other, wherein respective rotation axis of said two rollers (41, 42) are parallel to each other and parallel to said transversal direction (201), wherein a gap (h) between said two rollers (41, 42) is less than or equal to 1 mm and greater than or equal to 0.1 mm, and wherein a thickness (s) of the artificial yarn (3) is substantially equal to said gap (h) of the calender (104).

7. Process according to anyone of the preceding claims, wherein said heating comprises advancing the semi-finished yarn (1) along a first roll stage (103) comprising rollers at a stabilized temperature above said predetermined temperature, wherein said transversally stretching is completely carried out before at least part of said longitudinally stretching and wherein said predetermined temperature is a glass transition temperature of said polymeric material.

8. Process according to anyone of the preceding claims, wherein said longitudinally stretching comprises advancing said semi-finished yarn (1) along a first stretch (20), wherein a ratio of an advancement speed at an end of said first stretch and at a start of said first stretch is higher than 2, wherein said start of said first stretch (20) is immediately after said transversally stretching and said end of said first stretch is at a second roll stage (106), wherein said heating comprises keeping said rollers of the calender (104) at a set temperature above said predetermined temperature and passing the semi-finished yarn (1) through a first oven (105) along said first stretch (20), the process further comprising intermediate cooling the semi-finished yarn (1) after said longitudinally stretching by keeping rollers of the second roll stage (106) below said predetermined temperature.

9. Process according to anyone of the preceding claims, wherein a width (w) of the semi-finished yarn

(1) after said longitudinally stretching is smaller than a width (W) of said semi-finished yarn (1) immediately after the transversal stretching, and wherein a thickness (s) of the semi-finished yarn (1) after said longitudinally stretching is substantially equal to a thickness (s) of the semi-finished yarn (2) immediately after said transversally stretching.

10. Process according to anyone of the preceding claims, further comprising, subsequently to said transversally stretching and said longitudinally stretching and before said final cooling said semi-finished yarn (1), further heating said semi-finished yarn (1), wherein said further heating brings said semi-finished yarn (1) at a respective temperature greater than a maximum temperature of said semi-finished yarn (1) reached during said heating, wherein the process further comprises, during said further heating, longitudinally shrinking the semi-finished yarn (1) by advancing said semi-finished yarn (1) along a second stretch (30), wherein an advancement speed at an end of said second stretch is lower than at a start of said second stretch, wherein said further heating comprises passing the semi-finished yarn (1) through a second oven (107) along said second stretch (30).

11. Process according to anyone of the preceding claims, wherein said final cooling said semi-finished yarn (1) comprises advancing said semi-finished yarn (1) along a third roll stage (108) comprising rollers at a stabilized temperature less than or equal to 40°C, and wherein said cooling said semi-finished yarn (1) brings said semi-finished yarn (1) at a temperature less than or equal to 40°C and greater than or equal to 15°C.

12. Process according to anyone of the preceding claims, wherein said artificial yarn (3) has a percentage of polymeric chains overall oriented along said transversal direction (201) greater than or equal to 5%, and/or lower than or equal to 50%, of the overall length of the polymeric chains.

13. Process according to anyone of the preceding claims, wherein said artificial yarn (3) has a mass per unit of length greater than or equal to 500 dtex and less than or equal 4000 dtex, and wherein a ratio between a mass per unit of length of said semi-finished yarn (1) before both said transversally and longitudinally stretching and said mass per unit of length of said artificial yarn (3) is greater than or equal 2 and less than or equal 6.

14. Process for producing a synthetic turf mat, the process comprising:

- providing a support ply;
- producing an artificial yarn (3) according to the process of anyone of the preceding claims;
- fixing the artificial yarn (3) to the support ply for making artificial blades.

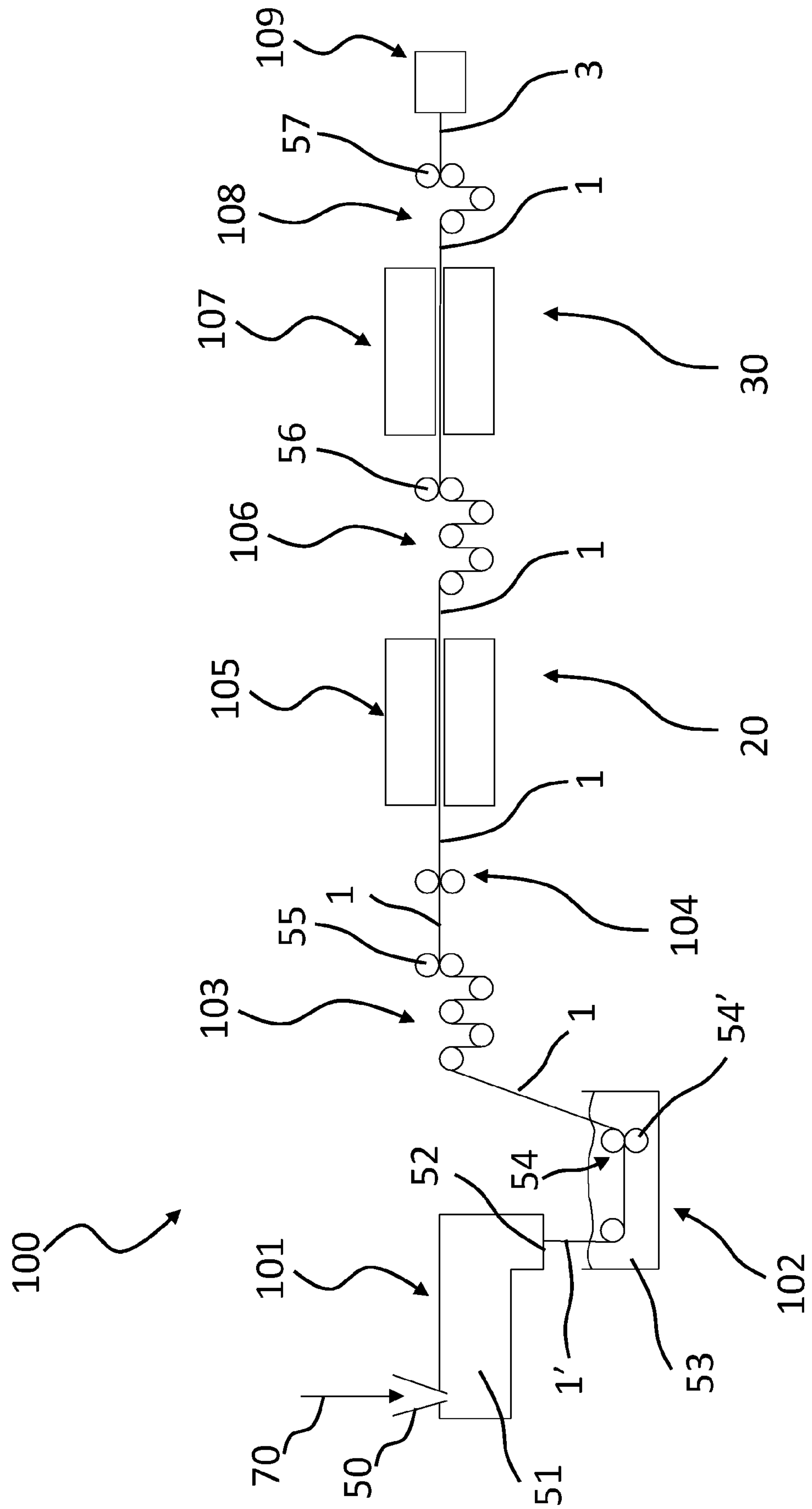
109
3
57
108
1
107
30
56
106
1
105
20
1
55
1
104
103
1
54'
52
54
100
101
102
1'
53
70
50
51

FIG. 1

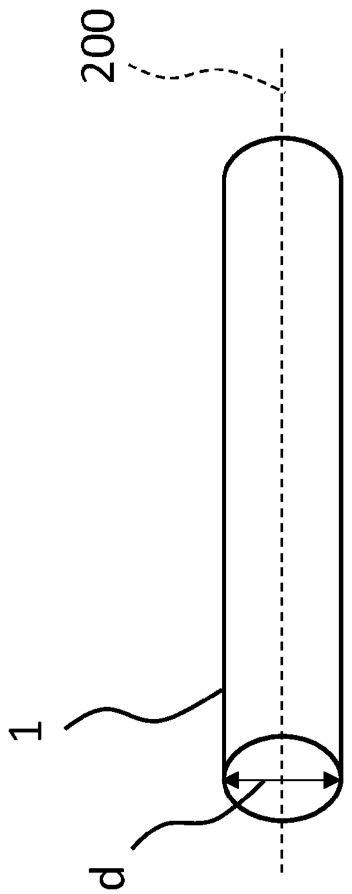

FIG. 2b

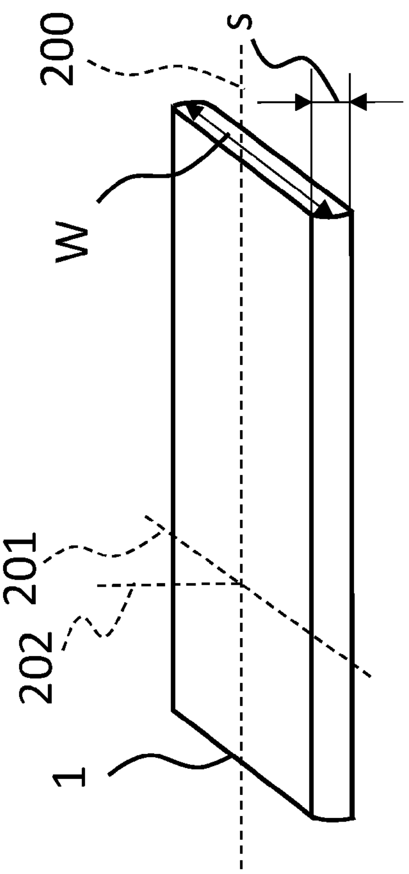

FIG. 2c

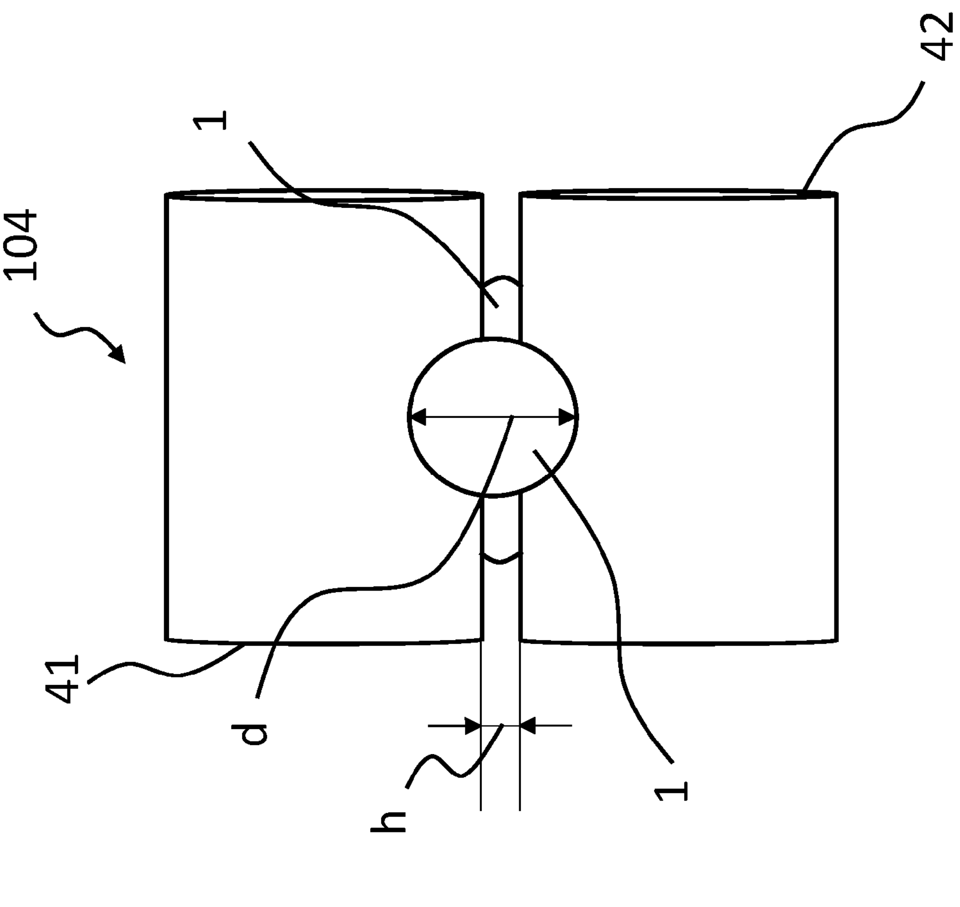

FIG. 2a

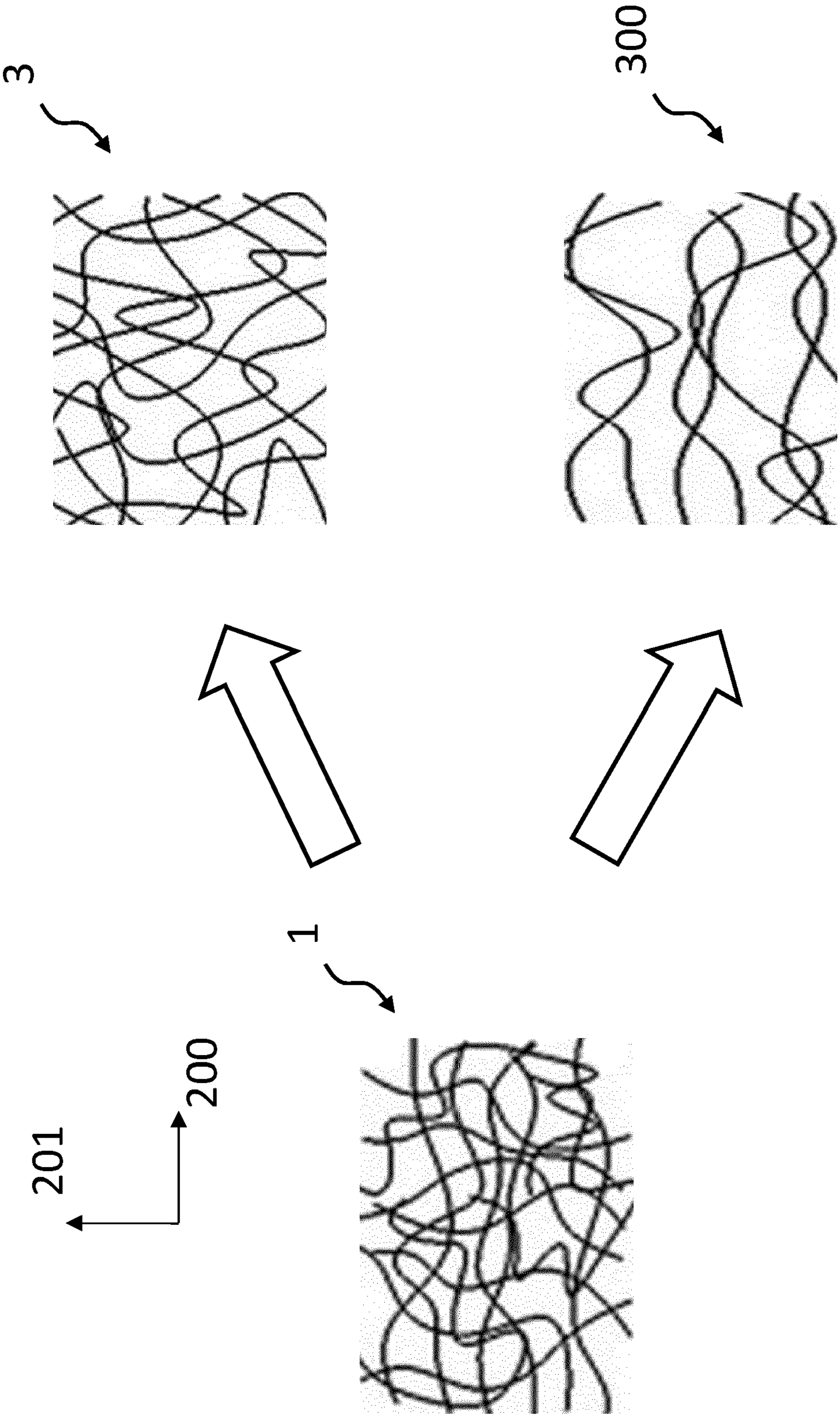

FIG. 3

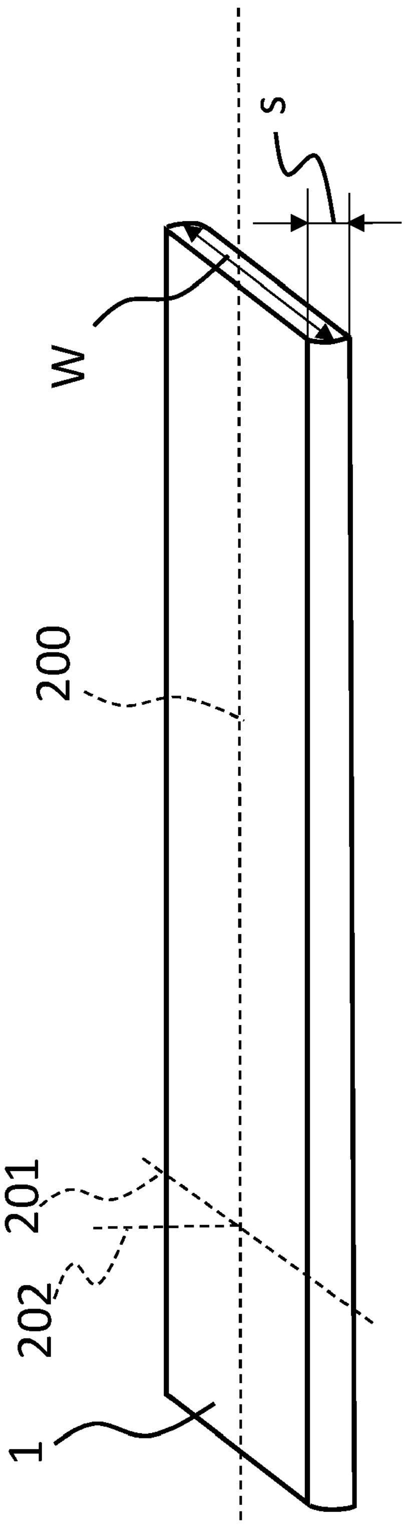

FIG. 4a

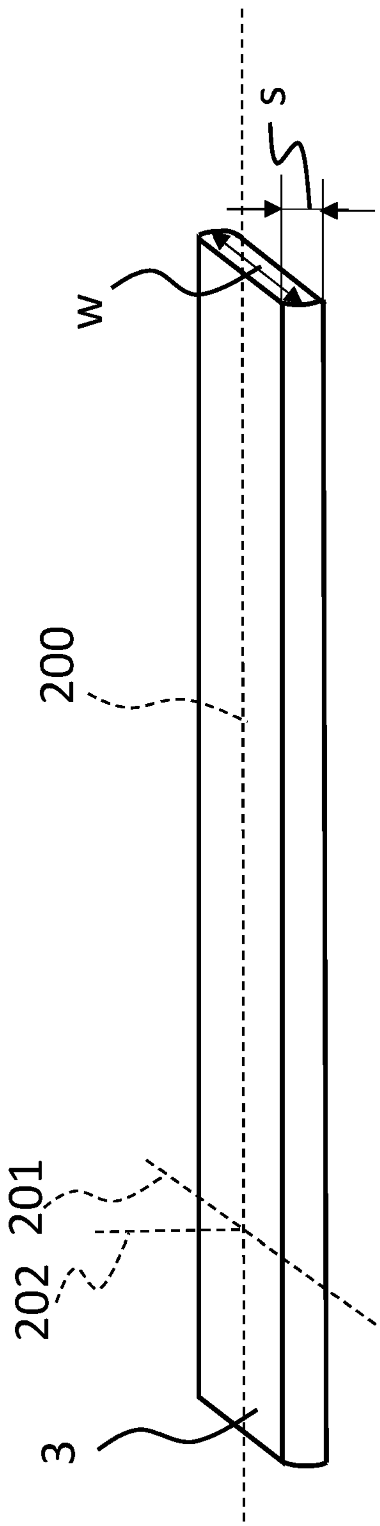

FIG. 4b

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 6535

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	JP 2016 000882 A (HAGIHARA IND) 7 January 2016 (2016-01-07) * paragraphs [0015], [0017], [0018], [0020], [0029], [0038]; example 1 * -----	1,5-7 2-4,8-14	INV. D01D5/16 D01F6/46 E01C13/08 D02J1/22
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TECHNICAL FIELDS SEARCHED (IPC)

D01F
E01C
D02J

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	15 April 2024	Van Beurden-Hopkins

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 20 6535

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