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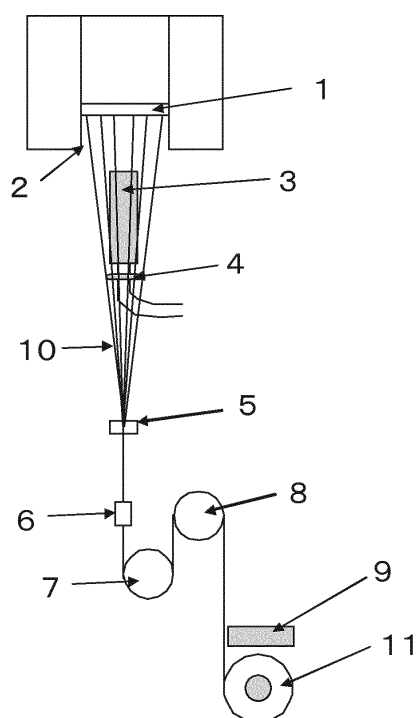
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(54) **ULTRAFINE POLYAMIDE FIBER, AND MELT-SPINNING METHOD AND DEVICE THEREFOR**

(57) This ultrafine polyamide fiber is a polyamide fiber having a single-filament fineness of 0.10-0.50 dtex, in which the average number of fluffs per 12,000 m of the length of the filaments is 1.0 or less. The melt-spinning method of the invention for producing the ultrafine polyamide fiber comprises: cooling melt-spun filaments discharged from a spinneret having orifices annularly disposed in the peripheral part of the spinneret, using a cooler (3) which is located under the center of the spinneret and which blows cooling air against the melt-spun filaments ejected from the orifices, from inside or outside the melt-spun filaments to cool the melt-spun filaments; oiling the filaments using an annular oiling device (4) that has a disk-shaped guide part which is located vertically under the cooler (3) and in which single filaments come into contact with the periphery of the disk and that has an annular slit for oil ejection which has been formed right over the guide part along the periphery of the guide; and then collecting the filaments and simultaneously performing second-stage oiling, by means of a collecting guide type oiling device (5).

Figure 1



Description

Technical field

5 **[0001]** The present invention relates to ultrafine polyamide fiber with a very small single yarn fineness, and more specifically relates to ultrafine polyamide fiber that serves to impart high softness, smoothness, drape property, high water absorption capacity, high density, and high post-dyeing quality to woven or knitted fabrics.

Background art

10 **[0002]** Having a wide range of good characteristics including mechanical characteristics, polyamide fibers have been widely used for production of clothing and industrial materials. Among other clothing materials, false-twisted yarns have been in wide use for products such as woven fabrics and knitted fabrics, and have been manufactured in large quantities. In particular, ultrafine false-twisted yarns with a single yarn fineness of 1.2 dtex or less can produce cloth having very soft texture as well as improved heat retaining and water absorption capacities compared with false-twisted yarns with common levels of single yarn fineness. Accordingly, ultrafine false-twisted yarns have been in increased demands and now dominate the market.

15 **[0003]** For these applications of ultrafine polyamide fibers, there is a proposal of ultrafine polyamide fiber intended for false-twisting that can impart softness to cloth as a result of being produced from ultrafine polyamide fiber for false-twisting containing fiber of polyamide resin with a single yarn fineness of 1.2 dtex or less and having specially specified friction coefficient, elongation percentage, and hot water shrinkage rate (patent document 1).

20 **[0004]** There is another proposal of polyamide fiber for false twisting useful to produce false-twisted crimped threads with high softness that is produced from polyamide fiber having a single yarn fineness of 1.2 dtex or less and also having a specially specified stress at 15% elongation and opening length of interlaced portions (patent document 2).

25 **[0005]** A proposed method for applying a finishing oil uniformly to these ultrafine polyamide fibers is to cool single yarns uniformly by means of a so-called ring chimney, which is an apparatus designed so that polymer threads discharged from a spinning spinneret with discharge holes arranged along a ring are cooled by applying cool air in all directions along their inner or outer circumferences, and subsequently apply a finishing oil from oil guides located opposite to each other with the yarns interposed in between (patent document 3).

30 **[0006]** There is another proposed method in which a finishing oil is supplied uniformly to single yarns on the downstream side of a spinning spinneret provided with a plurality of discharge holes arranged along a ring, by bringing the single yarns into contact with a plate located inside the plurality of filaments discharged from discharge holes (patent document 4).

35 Patent document 1: Japanese Unexamined Patent Publication (Kokai) No. 2005-320655

Patent document 2: Japanese Unexamined Patent Publication (Kokai) No. 2009-84749

Patent document 3: Japanese Unexamined Patent Publication (Kokai) No. 2007-126759

Patent document 4: Japanese Unexamined Patent Publication (Kokai) No. 2010-126846

40 Summary of the invention

Problems to be solved by the invention

45 **[0007]** However, if an attempt is made to produce still thinner ultrafine polyamide fiber with a fineness of 0.5 dtex or less by a method as described in patent documents 1 and 2, it will be difficult to achieve uniform cooling or uniform lubrication and result in ultrafine polyamide fiber suffering from large Uster unevenness and poor fuzzing quality. Furthermore, as a result of larger differences in fiber structure among single yarns, breakage of yarns and a decrease in reelability of yarns will take place when subjected to false twisting, or significant fuzzing will take place during warping when subjected to weaving or knitting, thus leading to disadvantages such as decreased smoothness and quality in cloth production and significant uneven dyeing in dyed cloth.

50 **[0008]** If applied to solving this problem, the finishing oil supply method described in patent document 3 will have to bundle the yarns while supplying a finishing oil. Ultrafine polyamide fibers with a single yarn fineness of 0.5 dtex or less have peculiar disadvantages that the strength of each single yarn decreases, that the single yarns rub each other during the bundling of yarns, and that the fiber before finishing oil supply has a large friction coefficient. Accordingly, the rubbing between single yarns and the rubbing between single yarns and the guides that take place before finishing oil supply will cause breakage of single yarns, prevent the finishing oil from being applied uniformly to single yarns in the inner portions of bundled yarns, cause differences in the amount of the finishing oil and water attached to single yarns, and cause differences in fiber structure among single yarns, thereby leading to dyed yarns with inferior quality.

[0009] If an attempt is made to apply the method described in patent document 4, uniform finishing oil supply will be difficult in the length direction of the fiber, although the single yarns can be lubricated uniformly. Furthermore, uneven adhesion of the finishing oil will take place in the length direction, leading to differences in fiber structure and a variation in friction coefficient in the length direction. Thus, there remain disadvantages that a variation in tension occurs in the length direction due to rubbing with yarn guides during the spinning step and high order processing steps, which leads to uneven dyeing in dyed yarns and failure in producing high-quality cloth.

[0010] The object of the present invention is to solve the above-mentioned problems with prior art and provide ultrafine polyamide fiber that serves to impart high softness, smoothness, drape property, high water absorption capacity, high density, and high post-dyeing quality to woven or knitted fabrics.

Means of solving the problems

[0011] The present invention adopts the following constitution to solve the problems described above.

(1) Ultrafine polyamide fiber comprising polyamide fiber with a single yarn fineness of 0.10 dtex or more and 0.50 dtex or less in which filaments have an average number of fuzzes of 1.0 or less per 12,000 m in the length direction.

(2) Ultrafine polyamide fiber as defined in (1) wherein the Uster unevenness of filaments in the length direction is 1.0% or less.

(3) Ultrafine polyamide fiber as defined in either (1) or (2) having a total fineness of 15 to 300 dtex and containing 30 or more filaments.

(4) Ultrafine polyamide fiber as defined in any of (1) to (3) wherein filaments have a modified cross section.

(5) Ultrafine polyamide fiber as defined in any of (1) to (3) comprising single yarns in which filaments have a circular filament cross section, wherein the orientation parameters of the single yarns with a circular cross section are such that the ratio of the orientation parameter of the surface portion of the single yarn to the orientation parameter of the central portion of the single yarn is 1.10 or more.

(6) A melt-spinning method for ultrafine polyamide fiber having a single yarn fineness of 0.10 dtex or more and 0.50 dtex or less and having an average of 1.0 or less fuzzes per 12,000 m in the length direction, wherein melt-spun yarns discharged from a spinning spinneret provided with discharge holes arranged circumferentially in the outer circumferential portion of the spinning spinneret are cooled by a cooling apparatus located below the central portion of the spinning spinneret and designed to cool the melt-spun yarns by applying cooling air from either inside or outside of the melt-spun yarns discharged from the discharge holes, and a finishing oil is supplied by a circular finishing oil supply apparatus having a disk-like guide portion that is located vertically below the cooling apparatus and that is in contact with the single yarns at its outer circumferential portion, and also having a circular finishing oil-discharging slit that is located directly above the guide portion and arranged along the outer circumference of the guide, followed by the bundling of yarns and second-stage finishing oil supply performed simultaneously by a bundle-guide type finishing oil supply apparatus.

(7) The melt-spinning method as defined in (6) wherein the cooling apparatus is designed to cool the melt-spun yarns by supplying cooling air from inside of the melt-spun yarns discharged from the discharge holes.

(8) The melt-spinning method as defined in either (6) or (7) wherein the cooling apparatus meets the following requirements:

(i) the distance (L) from the face of the spinning spinneret to the cooling start position of the cooling apparatus is as follows: $10 \text{ mm} \leq L \leq 70 \text{ mm}$, and

(ii) cooling air provided at the cooling start position has a flow speed of 15 to 60 m/min.

(9) A melting spinning apparatus for ultrafine polyamide fiber having a single yarn fineness of 0.10 dtex or more and 0.50 dtex or less and having an average of 1.0 or less fuzzes per 12,000 m in the length direction, that comprises a spinning spinneret provided with discharge holes arranged circumferentially in the outer circumferential portion of the spinning spinneret, and a cooling apparatus located below the central portion of the spinning spinneret and designed to cool the melt-spun yarns by applying cooling air from inside or outside of the melt-spun yarns discharged from the discharge holes, and further comprises a circular finishing oil supply apparatus having a disk-like guide portion that is located vertically below the cooling apparatus and that is in contact with the single yarns at its outer circumferential portion and also having a circular finishing oil-discharging slit that is located directly above the guide portion and arranged along the outer circumference of the guide, as well as a bundle-guide type finishing oil supply apparatus located thereunder and designed to bundle the yarns and perform second-stage finishing oil supply simultaneously.

(10) The melt-spinning apparatus as defined in (9) wherein the cooling apparatus is designed to cool the melt-spun yarns by applying cooling air from inside of the melt-spun yarns discharged from the discharge holes.

Effect of the invention

[0012] As described below, ultrafine polyamide fiber serving to produce woven or knitted fabrics with high softness, smoothness, drape property, high water absorption capacity, high density, and high post-dyeing quality that cannot be realized with conventional ultrafine polyamide fibers can be obtained according to the present invention using polyamide fiber that has a single yarn fineness of 0.10 dtex or more and 0.50 dtex or less and has an average of 1.0 or less fuzzes per 12,000 m in the length direction. In addition, excellent anti-see-through property can also be imparted according to a preferable embodiment.

Brief description of the drawings

[0013]

[Fig. 1] Fig. 1 is a diagram illustrating an example of the ultrafine polyamide fiber production method according to the present invention.

[Fig. 2] Fig. 2 is a diagram illustrating a shape example of spinneret holes to be used for production of the ultrafine polyamide fiber according to the present invention.

[Fig. 3] Fig. 3 is a diagram illustrating another shape example of spinneret holes to be used for production of the ultrafine polyamide fiber according to the present invention.

[Fig. 4] Fig. 4 is a diagram illustrating a preferred example of cyclic finishing oil supply apparatus to be used for production of the ultrafine polyamide fiber according to the present invention.

[Fig. 5] Fig. 5 is a diagram illustrating another example of the ultrafine polyamide fiber production method according to the present invention.

Description of embodiments

[0014] Embodiments of the present invention are described in detail below.

[0015] Polyamide used in the ultrafine polyamide fiber for the present invention is a homopolymer or a copolymer of polyamide, and such a polyamide is a melt-moldable polymer containing an amide bond that is formed from lactam, aminocarboxylic acid, or a salt of dicarboxylic acid with diamine.

[0016] There are no specific limitations on the polyamide to be used, and various useful polyamides are available, but polycapraamide (nylon 6) and polyhexamethylene adipamide (nylon 66) are preferable from the viewpoint of fiber-forming capability and dynamic characteristics. Usable copolymers of these polyamides such as nylon 6 and nylon 66 include those in which other units such as aminocaproic acid and lactam account for 20 mol% or less of the total monomer units.

[0017] It is preferable that a polyamide to be used for the present invention has a sulfuric acid relative viscosity of 2.0 to 3.5, more preferably 2.4 to 3.0, and still more preferably 2.5 to 2.7, from the viewpoint of yarn-making stability. The sulfuric acid relative viscosity should be determined by the method described later.

[0018] In addition to the primary component, second and third components may be copolymerized with or mixed in the polymer used for the present invention as long as they meet the object of the present invention.

[0019] In particular, the polyamide may contain polyvinyl pyrrolidone if hygroscopicity is required in addition to meeting the object of the present invention.

[0020] Furthermore, the polyamide used for the present invention may contain various additives including, for instance, delustering agent, flame retardant, antioxidant, ultraviolet absorber, infrared ray absorbent, crystal nucleating agent, and fluorescent whitening agent, as required.

[0021] There are no specific limitations on the ultrafine polyamide fiber production method to be used for the present invention as long as ultrafine polyamide fiber according to the present invention can be obtained, but a preferred process includes the steps of melting polyamide, discharging it from discharge holes arranged circumferentially in the outer circumferential portion of a spinning spinneret, cooling it by a cooling apparatus located below the central portion of the spinneret and designed to cool the melt-spun yarns rapidly and uniformly by applying cooling air from inside or outside of the melt-spun yarns discharged from the discharge holes, and subsequently supplying a finishing oil to each single yarn by a circular finishing oil supply apparatus located vertically below the cooling apparatus, followed by bundling of the yarns and second-stage finishing oil supply performed simultaneously by a bundle-guide type finishing oil supply apparatus. A one-process method in which the second-stage finishing oil supply is followed by steps for interlacing the yarns and winding them up into a package, as required, is preferred because polyamide fiber with particularly small fineness unevenness and fuzzing can be obtained and from the viewpoint of cost reduction. The cooling apparatus is preferably a circular type cooling apparatus, more preferably an outward blow type circular cooling apparatus that supply cooling air from inside toward outside of the spun yarns running on circular circumferences or an inward blow type circular cooling apparatus that supply cooling air from outside toward inside of the spun yarns. The use of an outward

blow type circular cooling apparatus is particularly preferable.

[0022] A preferable example of the polyamide fiber production method according to the present invention is described in detail with reference to Figs. 1 to 5. Figs. 1 to 5 are schematic diagrams illustrating an example of the polyamide fiber production method according to the present invention. Fig. 1 gives an example that uses an outward blow type circular cooling apparatus 3, and Fig. 5 gives an example that uses an inward blow type circular cooling apparatus 18. In the following description, the production processes shown in Fig. 1 and Fig. 5 consist of basically the same constituents, and descriptions of constituents with the same numerals are omitted.

[0023] In Fig. 1, molten polyamide is discharged through a spinneret 1 and passed through a heat retaining zone 2 under the spinneret, and subsequently, cooling air is applied from inside toward outside of the spun yarns by an outward blow type circular cooling apparatus 3 installed below the spinneret center in order to reduce fineness unevenness in the length direction, thereby rapidly cooling the single yarns at a uniform distance from the spinneret face to cause their solidification. Before bundling the yarns, it is preferable that a finishing oil is supplied to each single yarn by a circular finishing oil supply apparatus 4 having a disk-like guide portion that is in contact with the single yarn at the outer circumferential portion of the disk and also having a finishing oil-discharging circular slit formed directly above the guide portion and along the outer circumference of the guide, followed by bundling of the yarns and second-stage finishing oil supply performed simultaneously by a bundle-guide type finishing oil supply apparatus 5. After the finishing oil supply step, the yarns are interlaced by an interlacing nozzle 6 as required, and wound up by a winder (wind up apparatus) 9 after passing on a take-up roller 7 and a drawing roller 8. Fiber filaments 10 and a package of the fiber product 11 are also shown. Two or more sets of rollers may be used for drawing before winding-up into a package, but in that case, the draw ratio should be low because the interlaced yarns can become loose as a result of drawing, or an interlacing step may be performed again after drawing.

[0024] In the heat retaining zone 2 under the spinneret, the practice of blowing out steam toward the spinneret face to fill the heat retaining zone 2 under the spinneret with steam is preferred because this prevents the polymer and oligomers contained in the polymer existing around the discharge holes of the spinneret from reacting with oxygen to solidify and contaminate the spinneret. For this operation, it is preferable that the steam blow-out pressure is 0.1 to 0.5 kPa. If the blow-out pressure is too low, the oxygen concentration in the heat retaining zone under the spinneret will be high and impair the spinneret face contamination prevention effect, whereas if the blow-out pressure is too high, it will cause swinging of discharged yarns and lead to an increased Uster unevenness.

[0025] For cooling spun yarns arranged on circular circumferences, the use of a circular type cooling apparatus to apply radial outward cooling air to the yarns is preferred because oligomer components formed from the polyamide discharged from the spinneret and the steam that seals the spinneret face will be prevented from retaining inside the spinning apparatus and will be released outside.

[0026] An outward blow type circular cooling apparatus 3 is used in the production process shown in Fig. 1, but an inward blow type circular cooling apparatus 18 as illustrated in Fig. 5 may be used instead of the outward blow type circular cooling apparatus 3. The inward blow type circular cooling apparatus 18 will be installed so as to surround the spun yarns below the spinneret center and serve to apply cooling air from outside toward inside of the spun yarns, thereby rapidly cooling the single yarns at a uniform distance from the spinneret face to cause their solidification.

[0027] It is preferable that the cooling start distance, that is, the distance (L) from the spinneret face to the top of the cooling air blow-out portion of the circular type cooling apparatus, is 10 to 70 mm, more preferably 10 to 60 mm, and still more preferably 10 to 50 mm. If the cooling start distance is too short, the cooling air blown out of the circular type cooling apparatus hits the spinneret face to lower the temperature of the spinneret face, and accordingly, the discharge stability of the thermoplastic polymer will deteriorate, leading to increased breakage and fuzzing of the spun yarns. If the cooling start distance is too long, the polyamide will start to solidify before the start of rapid, uniform cooling by cooling air, and accordingly, the fineness variation (Uster unevenness) tends to increase in the fiber's length direction, resulting in cloth with poor quality.

[0028] It is preferable that the flow speed of the cooling air from the circular type cooling apparatus is 15 to 60 m/min, more preferably 20 to 55 m/min, and still more preferably 25 to 50 m/min. If the flow speed of the cooling air is too low, uniform rapid cooling of the single yarns will not be achieved sufficiently, and the tension on the cooled yarns will be small. Accordingly, swing of the yarns tends to be caused easily by outside disturbances, leading to increased Uster unevenness. Furthermore, the polymer can come in contact with the guide before being cooled adequately, and accordingly, fuzzing and breakage of spun yarns will take place frequently, resulting in cloth with inferior quality. If the flow speed of the cooling air is too high, each single yarn will suffer from excessive tension to cause slight vibration of the yarn, leading to increased Uster unevenness and frequent yarn breakage during spinning.

[0029] It is preferable that the temperature of the cooling air from the circular type cooling apparatus is 5 to 50°C, more preferably 10 to 40°C, and still more preferably 15 to 35°C. If the temperature of the cooling air is too low, the temperature in the heat retaining zone under the spinneret will fall and the temperature of the spinneret face will also fall, often leading to a decrease in the strength of the yarns, whereas if the temperature of the cooling air is too high, uniform cooling of the yarns will become difficult and the yarns will not be cooled sufficiently, often leading to increased Uster unevenness

and frequent yarn breakage during spinning.

[0030] It is preferable that the vertical length of the cooling air supply portion of the circular type cooling apparatus is 100 to 500 mm, more preferably 150 to 400 mm, and still more preferably 200 to 350 mm. If the length of the cooling air supply portion is too large, each single yarn will suffer from increased tension to cause breakage of spun yarns, whereas if the length of the cooling air supply portion is too small, the single yarns will receive a finishing oil before being cooled adequately, possibly leading to decreased fuzzing and breakage of spun yarns.

[0031] After passing the circular type cooling apparatus, the single yarns can be subjected to treatment by a circular finishing oil supply apparatus. The circular finishing oil supply apparatus is located inside the spun yarns running on circular circumstances.

[0032] Fig. 4 is a conceptual diagram illustrating an example of a circular finishing oil supply apparatus used favorably for the present invention. This circular finishing oil supply apparatus 4 contains a finishing oil-discharging slit 12 and a disk-like guide 13. The circular finishing oil supply apparatus 4 is installed so that the fiber filaments (single yarns) 14 coming from the circular type cooling apparatus are in contact with the disk-like guide 13. A circular finishing oil-discharging slit 12 is formed along the outer circumference of the disk-like guide 13 so that a finishing oil is supplied to positions directly above the contact points of the disk-like guide 13 with the yarns. The finishing oil is fed from a finishing oil feed pipe 17 to a finishing oil liquid pool 15. The finishing oil filling the finishing oil pool 15 is then discharged through the finishing oil-discharging slit 12 and comes in contact with each single yarn at the contact point with the yarn on the disk-like guide 13, thus lubricating each single yarn.

[0033] The bringing of the single yarns coming from the circular type cooling apparatus into contact with the disk-like guide is preferred because swinging of the single yarns receiving cooling air is prevented and uniform cooling of the single yarns is promoted, leading to decreased Uster unevenness. Furthermore, the use of a circular finishing oil supply apparatus that gives a finishing oil to each single yarn before the bundling of the yarns by discharging the finishing oil through a finishing oil-discharging circular slit that is located directly above the contact points of the disk-like guide with the yarns and along the outer circumference of the guide is preferred because this can effectively prevent unlubricated yarns with high frictional resistance from coming in contact with the disk-like guide and depress fuzzing due to rubbing of unlubricated single yarns with each other during the bundling of yarns, and this also serves for uniform lubrication of single yarns which cannot be achieved by the finishing oil supply from the bundle-guide type finishing oil supply apparatus, thus preventing fuzzing due to rubbing of unlubricated single yarns with the yarn guide during the spinning process as well as uneven dyeing during the dyeing process, to provide fiber suitable for high-order processing. It is preferable that the circular finishing oil supply apparatus is located so as to supply a finishing oil at a position 300 to 1,000 mm, more preferably 350 to 700 mm, and still more preferably 400 to 600 mm, from the spinneret face. If the finishing oil supply position is too high, the finishing oil will be supplied before the single yarns have been cooled adequately, possibly causing filament strength deterioration and fuzzing, whereas if it is too low, an increased distance will be required from the discharge of single yarns from the spinneret face to their bundling point, and accordingly, this will cause swinging of yarns, fuzzing, increased Uster unevenness, and increased air dragging by single yarns, leading to increased tension on running yarns and breakage of spun yarns. There are no specific limitations on the type of finishing oil to be supplied by the circular finishing oil supply apparatus, but it is preferable that the finishing oil is of an emulsion type. An emulsion finishing oil can easily form a film on the guide due to surface tension, permitting uniform finishing oil supply along the circumference of the disk-like guide.

[0034] The adoption of a two-stage finishing oil supply consisting of finishing oil supply by a circular finishing oil supply apparatus 4 and additional finishing oil supply and bundling of single yarns performed simultaneously by a bundle-guide type finishing oil supply apparatus 5 is preferred because it serves for uniform lubrication both among single yarns and in their length direction. It is difficult for the circular finishing oil supply apparatus 4 to obtain fibers lubricated uniformly in the length direction although it, although the circular finishing oil supply apparatus 4 can supply a finishing oil uniformly among single yarns, but the two-stage finishing oil supply by the bundle-guide type finishing oil supply apparatus 5, which serves for uniform lubrication in the length direction, and the circular finishing oil supply apparatus 4 permits uniform lubrication both among single yarns and in their length direction, making it possible to provide ultrafine polyamide fiber that ensures high post-dyeing quality.

[0035] The bundle-guide type finishing oil supply apparatus used for the second-stage lubrication may adopt a common type finishing oil supply guide, and for instance, a finishing oil supply guide as shown in patent document 3 is preferred.

[0036] It is preferable that the yarn take-up speed of the take-up roller 7 is 3,500 to 4,500 m/min. If the take-up speed is too low, the orientation of the polyamide in the length direction will be unstable and uneven dyeing will take place in the length direction, whereas if the take-up speed is too high, the yarns will suffer from large tension, possibly causing fuzzing and breakage of spun yarns. It is preferable that the draw ratio for the drawing roller 8 is 1.0 to 1.3. If the draw ratio is too high, the resulting fiber will be too low in elongation percentage, and in addition, breakage of single yarns will cause fuzzing easily.

[0037] The ultrafine polyamide fiber according to the present invention is required to have a single yarn fineness of 0.1 dtex or more and 0.5 dtex or less, preferably 0.25 to 0.45 dtex. If the fineness of the single yarns is too large, the

yarns will have an excessively high rigidity and when woven or knitted into a fabric, it will be difficult to obtain a woven or knitted fabric with required high softness, smoothness, drape properties, high water absorption ability, and high density, whereas if the fineness of the single yarns is too small, breakage of single yarns will take place frequently during cloth production, and the resulting cloth will tend to suffer from fuzzing and inferior smoothness as well as increased Uster unevenness, leading to cloth with inferior post-dyeing quality. The fineness of single yarns should be measured by the method described later.

[0038] In the ultrafine polyamide fiber according to the present invention, the average number of fuzzes per 12,000 m of filaments in the length direction should be 1.0 or less. An average number of fuzzes of larger than 1.0 will lead to fuzzing caused by warping during weaving or knitting, and breakage of threads during false twisting, as well as poor reelability, and furthermore, woven or knitted fabrics produced from them will be poor in smoothness and quality. It is preferable that the average number of fuzzes per 12,000 m in the length direction is 0.5 or less, more preferably 0. To reduce the number of fuzzes, it is preferable to prevent unlubricated single yarns with large frictional resistance from rubbing each other and to supply a finishing oil from a circular finishing oil supply guide before bundling of yarns. The average number of fuzzes should be measured by the method described later.

[0039] In general, fibers have a variation in yarn fineness in the length direction, and thicker portions of yarns tend to be dyed more strongly during dyeing. In particular, this occurs more significantly in the case of single yarns with small fineness. Fibers with large fineness unevenness will lead to woven or knitted fabrics with poor appearance due to decreased dyeing uniformity, and therefore, it is preferable that the Uster unevenness (fineness unevenness) is 1.0% or less. If the Uster unevenness is too large, the yarns will suffer from a large variation in smoothness and color depth during dyeing, and products produced will tend to be poor in quality. It is preferable that the Uster unevenness is 0.9% or less. There are no specific limitations on the method to be used for decreasing the Uster unevenness, but preferable methods include rapid cooling by bringing a cooling air blow-out apparatus closer to the spinneret face, and supply of annular flow of cooling air to yarns from outer circumference and /or inner circumference. A more preferable method is to cool single yarns uniformly by supplying annular flow of cooling air from the inner circumference of the yarns, followed by bringing the single yarns in contact with a disk-like guide to prevent swinging of the yarns. For the present invention, the Uster unevenness (fineness unevenness) should be measured by the method described later.

[0040] If the ultrafine polyamide fiber according to the present invention contains single yarns with a circular cross section, it is preferable that the orientation parameter of the surface portion of those yarns and the orientation parameter of their central portion differ from each other. If the orientation parameter differs between the surface portion and the central portion, the refractive index will differ between light passing through the central portion and that through the surface portion of the ultrafine polyamide fiber, and consequently, anti-see-through property can be developed despite the circular cross section. Specifically, it is preferable that the ratio of the orientation parameter of the surface portion of a single yarn to the orientation parameter of the central portion of the single yarn is 1.10 or more, more preferably 1.15 or more and 2.00 or less, and still more preferably 1.20 or more and 1.80 or less. If the ratio of the orientation parameter of the surface portion of a single yarn to the orientation parameter of its central portion is in the above range, light passing in the cross-sectional direction of the single yarn undergoes diffuse reflection and therefore, cloth produced from such single yarns will have anti-see-through property. In addition, excessively large strain will not occur in the internal structure of the fiber, serving to maintain adequate filament strength. The orientation parameter should be measured by the method described later. Ultrafine polyamide fiber with such orientation parameter values can be produced under preferred conditions as described above where the cooling start distance is not too large while the flow speed of the cooling air (cooling air speed) is not too low.

[0041] The ultrafine polyamide fiber according to the present invention has a very small single yarn fineness, and fiber in which the orientation parameter structure of the surface portion differs from the orientation parameter structure of the central portion can be obtained by cooling melt-spun yarns uniformly and rapidly. The ratio of the orientation parameter of the surface portion to the orientation parameter of the central portion tends to increase when cooling conditions serving for more rapid and uniform cooling are adopted.

[0042] Furthermore, it is preferable that this ultrafine polyamide fiber has an elongation percentage of 40 to 70%. If the elongation percentage is too low, the tensile resistance of filaments will increase, leading to a decrease in the actual number of twists that are added by false-twisting and making it difficult to produce textured yarn with adequate crimps. In addition, drawn yarns will tend to suffer from yarn breakage and fuzzing and deteriorate in high-order passage capability. If the elongation percentage is too large, on the other hand, the actual number of added twists will increase excessively, often resulting in textured yarns suffering from fuzzing or a decrease in strength or drawn yarns with a high residual elongation percentage that leads to woven or knitted fabrics suffering from streaks and deterioration in quality. The elongation percentage should be measured by the method described later.

[0043] Furthermore, it is preferable that the stress required for 15% elongation of the resulting ultrafine polyamide fiber is 1.0 to 2.0 gf/dtex (9.8×10^{-3} to 19.6×10^{-3} N/dtex), more preferably 1.2 to 1.8 gf/dtex (11.8×10^{-3} to 17.6×10^{-3} N/dtex). If the stress at 15% elongation is too small, the tension caused during a false-twisting process will be too small, often causing breakage of textured yarns, fluctuation in processing tension, quality deterioration of textured yarns,

and decreased yield. If the stress at 15% elongation is too large, on the other hand, a false-twisting process will cause high-degree concentration of tension in interlaced portions and breakage of single yarns, leading to deterioration in process passage capability and woven or knitted fabrics with decreased quality. The stress at 15% elongation should be measured by the method described later.

[0044] It is preferable that the ultrafine polyamide fiber according to the present invention has a total fineness of 15 to 300 dtex, more preferably 15 to 200 dtex. If the total fineness is too small, the breaking strength of the fiber will be too small, leading to cloth with an excessively small tearing strength, whereas if the total fineness is too large, dyes will not penetrate easily into the fiber during dyeing and uneven dyeing will remain after dyeing, making it difficult to obtain high-quality cloth. The total fineness should be measured by the method described later.

[0045] It is preferable that the ultrafine polyamide fiber according to the present invention has a filament number of 30 or more, more preferably 30 to 500, still more preferably 50 to 400. If the filament number is less than 30, it will be difficult to obtain an intended high softness, drape property, high water absorption capacity, and high density, whereas if the filament number is too large, it will lead to difficulty in uniform interlacing, deterioration in reelability, and difficulty in uniform finishing oil supply to filaments, resulting in fuzzing attributable to breakage of single yarns.

[0046] There are no specific limitations on the cross-sectional shape of the ultrafine polyamide fiber according to the present invention, and it may have, for instance, either a circular cross section or a modified cross section. Applicable modified cross sections include, for instance, oblate cross section, lens-shaped cross section, trilobal cross section, hexalobal cross section, so-called multilobar cross section such as modified cross section containing 3 to 8 convex portions and the same number of concave portions, hollow cross section, and other generally known modified cross-sections. The circular cross section is preferable from the viewpoint of spinning stability, high softness, and drape property imparting capability. Furthermore, if the ultrafine polyamide fiber has a circular cross section with a preferable orientation parameter ratio between the central portion and the surface portion as described above, light passing in the cross-sectional direction of the single yarn will undergo diffuse reflection due to differences in orientation structure, whereas if it has a trilobal cross section, multilobar cross section, or hollow cross section, light passing through the surface undergo diffuse reflection. Thus, they are preferable because cloth produced will have good anti-see-through property due to diffuse reflection of transmitted light. Furthermore, a trilobal cross section, a multilobar cross section, and a mixture of filaments with a multilobar cross section and those with a circular cross section are preferred because they serve to produce cloth containing many gaps among single yarns, leading to large water absorption capacity attributable to capillarity effect as well as high bulk density. They are also preferred because they can impart anti-see-through property attributable to diffuse reflection of transmitted light.

[0047] The resulting ultrafine polyamide fiber according to the present invention serves to produce cloth having high softness, smoothness, drape property, high water absorption capacity, high density, and high post-dyeing quality, as well as good anti-see-through property in the case of a preferred embodiment. Thus, woven fabrics produced from the ultrafine fiber according to the present invention is preferred as high heat-insulating lightweight material for outerwear such as down jacket. Knitted fabrics serve favorably for production of luxurious underwear having good functions as listed above as well as covered yarns for tights.

Examples

[0048] The invention is described in more detail below with reference to Examples.

[0049] The characteristic values used in the present Description and Examples were determined by the following methods.

(1) Total fineness and single yarn fineness

[0050] Using a sizing reel with a circumference of 1.000 m, a specimen (yarn) of 27 decitex or less was wound 1,000 times and a specimen of 28 decitex or more was wound 500 times to prepare skeins, which were dried in a hot air drier at $105 \pm 2^\circ\text{C}$ for 60 min and weighed to on a balance, followed by calculating the total fineness from the measurements using the following equation (i) or (ii). The total fineness thus calculated was divided by the number of single yarns to determine the single yarn fineness.

(i) Yarn of 27 decitex or less

$$\text{Total fineness (dtex)} = \text{measured weight (g)} \times (10,000/1,000) \times \{1 + (\text{standard moisture content (\%)/100})\}$$

(i) Yarn of 28 decitex or more

Total fineness (dtex) = measured weight (g) $\times$ (10,000/500) $\times$ {1 + (standard moisture content (%)/100)}

For the nylon 6 and nylon 66 polymers used in Examples, a standard moisture content of 4.5% was used for the fineness calculation.

Single yarn fineness (dtex) = total fineness (dtex) / number of single yarns

To determine the single yarn fineness of combined filament yarns with two different cross-sectional shapes (cross section A and cross section B), the cross section ratio of the single yarn of each cross-sectional shape was calculated by the following equations, and the total fineness obtained above was multiplied by the cross section ratio for either cross-sectional shape and divided by the total number of the filaments of that shape.

Area ratio of cross section A = area of cross section A / (area of cross section A + area of cross section B)

Area ratio of cross section B = area of cross section B / (area of cross section A + area of cross section B)

Single yarn fineness (dtex) for cross section A in combined filament yarns = (total fineness (dtex) $\times$ area ratio of cross section A) / number of filaments of cross section A

Single yarn fineness (dtex) for cross section B in combined filament yarns = (total fineness (dtex) $\times$ area ratio of cross section B) / number of filaments of cross section B

(2) Sulfuric acid relative viscosity

[0051] A specimen is weighed and dissolved in 98 wt% concentrated sulfuric acid to prepare a solution with a specimen concentration (C) of 1 g/100 ml. It is put in an Ostwald viscometer and its falling time in seconds (T1) was measured at 25°C. Elsewhere, the falling time in seconds (T2) is measured at 25°C for the 98 wt% concentrated sulfuric acid free of the specimen, and then the relative viscosity (η_r) of the specimen is calculated by the following equation:

$$(\eta_r) = (T1 / T2) + \{1.891 \times (1.000 - C)\}$$

(3) Average number of fuzzes

[0052] For determination of the average number of fuzzes, Maluti-Point Fray Counter MFC-200 (F-type sensor unit) supplied by Toray Engineering Co., Ltd. (presently, TMT MACHINERY, INC.) was used under conditions including fuzz length setting (distance from sensor light axis center to U-Guide bottom) of 2.0 mm, yarn speed of 600 m/min, and measuring time of 20 min. After confirming that the yarn feeding tension is in the range of 0.25 g/dtex to 0.75 g/dtex, 10 measurements were made and their average was taken as the average number of fuzzes (per 12,000 m).

(4) Orientation parameter ratio

[0053] The orientation parameter was measured for specimens (single yarn) with a circular cross section by Raman spectroscopy using T-64000 supplied by Jobin Yvon/Atago Bussan Co., Ltd., under the following conditions: measuring mode of microscopic Raman, objective lens magnification of $\times 100$, beam diameter of 1 μ m, light source of Ar⁺ laser/514.5 nm, laser power of 100 mW, diffraction grid of Single 600, 1,800 gr/mm, slit of 100 μ m, and detector of CCD 1024x256 supplied by Jobin Yvon. A test sample was embedded in resin (bisphenol epoxy resin, cured for 24 hours)

and cut with a microtome at a cutting angle of 5° or less from the fiber's length direction to prepare a section specimen. A section specimen with a thickness of 1.5 μm was cut out so that it passes through the center of the fiber. Orientation was measured under two polarized conditions: parallel polarization (//) where the polarizing direction is parallel with the fiber's length direction and perpendicular polarization (⊥) where they are perpendicular to each other. The degree of orientation was evaluated based on the ratio between the peak strength (I_{1130}) attributable to the C-C bending vibration mode near 1130 cm⁻¹ and the peak strength (I_{1635}) attributable to the C=C stretching vibration near 1635 cm⁻¹ in Raman band measurements made under those conditions. Specifically, orientation parameter = (I_{1130}/I_{1635}) // / (I_{1130}/I_{1635}) ⊥. Regarding the measuring points, a laser beam was applied to a point 1 μm inner from the surface portion of a single yarn for the orientation parameter of the surface portion and a point in the central portion of a single yarn for the orientation parameter of the central portion, and the measurements made were used for orientation parameter calculation. From the results obtained, the ratio of the orientation parameter of the surface portion to the orientation parameter of the central portion was calculated by the following equation. For the orientation parameters of the surface and the central portion, five single yarns were selected at random from the filaments and the average of their measurements was used.

$$\text{Orientation parameter ratio} = (\text{orientation parameter of surface portion of single yarn}) / (\text{orientation parameter of central portion of single yarn})$$

(5) Uster unevenness

[0054] The Uster unevenness (1/2 inert, U%) was measured by using Uster Tester UT-4 supplied by Zellweger Uster under the following measuring conditions: yarn speed of 50 m/min, S-twist, twisting rate of 8,000 rpm, measuring time of 3 min.

(6) Stress at 15% elongation

[0055] Orientec Tensiron RPC-1210A was used to measure the stress at 15% elongation. A specimen was held by clamps 50 cm apart from each other and stretched at a tensile speed of 50 cm/min until a length of 57.5 cm was reached, when the tension was measured. Three test runs were made and their average was divided by the fineness of the fiber.

(7) Elongation percentage

[0056] Orientec Tensiron RPC-1210A was used to measure the elongation percentage. A specimen was held by clamps 50 cm apart from each other and stretched at a tensile speed of 50 cm/min until the specimen was broken, when the elongation was measured. Three test runs were made and their average was divided by 50 cm and multiplied by 100.

(8) Softness of cloth

[0057] Cloth was produced from the resulting fiber and dyed, and then it was subjected to tactile and visual tests for softness, surface smoothness, drape property, and depth of the color of cloth, and evaluated according to the following four-rank criteria.

- (A) Very good (Dyed cloth has softness, surface smoothness, and drape property. The cloth surface is free of fuzzing.)
- (B) Good (Good in terms of softness and drape property, but inferior in smoothness. Part of the surface contains fuzz.)
- (C) Slightly poor (Good in drape property, but inferior in softness and smoothness. Part of the surface contains fuzz.)
- (D) Poor (Cloth is stiff, and inferior in smoothness and drape property. Surface contains fuzz.)

(9) Dyeing quality of cloth

[0058] The resulting fiber was used for both warp and weft to produce a plain weave fabric with a pick length of 180 cm. The cloth was dyed with an acidic dye (Mitsui Nylon Black GL). The dyed plain weave fabric was evaluated by 10 testers using a see-through cloth inspecting machine. A 100 m portion in the length direction was inspected and relative evaluation was conducted according to the following criteria.

- (A) Completely free of streaks and color depth irregularity.
- (B) Containing slight streaks and color-depth irregularity, but practically acceptable.
- (C) Containing many slight streaks and color-depth irregular portions, and practically unacceptable.
- (D) Containing many serious streaks and color-depth irregular portions, and practically unacceptable.

(10) Water absorption capacity of cloth (Byreck method)

[0059] Measurements were made according to JIS L 1096 (1999) "Byreck Method". Evaluation was conducted according to the following criteria based on measured water absorption height.

- (A) 90 mm or more
- (B) 65 mm or more and less than 90 mm
- (C) 55 mm or more and less than 65 mm
- (D) less than 55 mm

(11) Anti-see-through property of cloth

[0060] A tube knit fabric was produced from the resulting fiber and inspected by 10 testers. After scouring, the anti-see-through property of the fabric was evaluated according to the following criteria.

- (A) Very good (Completely free of perceived see-through property, and acceptable as anti-see-through material)
- (B) Good (Slightly suffering from perceived see-through property, but practically acceptable as anti-see-through fabric)
- (C) Practically acceptable (practically useful for common uses)
- (D) Poor (Transparency strongly perceived, and unacceptable as fabric for underwear)

(12) Overall evaluation of cloth

[0061] Overall quality of cloth was evaluated according to the following criteria.

- (A) Ranked as either (A) or (B) for all four items of softness, dyeing quality, water absorption capacity, and anti-see-through property of cloth. Ranked as (A) at least for two items.
- (B) Ranked as (C) for one or less of the four items of softness, dyeing quality, water absorption capacity, and anti-see-through property of cloth. Ranked as (D) for none of them.
- (C) Ranked as (C) for two or more of the four items of softness, dyeing quality, water absorption capacity, and anti-see-through property of cloth, although ranked as (D) for none of them.
- (D) Ranked as (D) for one or more of the four items of softness, dyeing quality, water absorption capacity, and anti-see-through property of cloth.

Example 1

[0062] A nylon 66 material with a 98% sulfuric acid relative viscosity of 2.63 is melted at 285°C, supplied to a melt-spinning pack, and discharged from a spinneret provided with 98 circular holes. The single yarns are passed through a steam blow-out zone where steam is blown out toward the spinning spinneret face at a pressure of 0.25 kPa, then passed through a stand-alone, outward blow type circular cooling apparatus provided with a cooling air supply portion that is located on the downstream side of the steam blow-out zone, has a cooling start distance of 30 mm, and has a vertical length of 300 mm, and solidified as they are cooled by cooling air at 20°C supplied radially outward at a flow speed of 40 m/min. Subsequently, an emulsion finishing oil was supplied at a position 500 mm from the spinneret face by a circular finishing oil supply apparatus having a disk-like guide portion that is in contact with the single yarns at its outer circumferential portion and also having a circular finishing oil-discharge slit that is located directly above the guide portion and along the outer circumference of the guide, and the yarns are subjected to second-stage lubrication and bundled by a bundle-guide type finishing oil supply apparatus. They are taken up at 4,000 m/min while being interlaced, and then drawn at a draw ratio of 1.10, and wound into a package at 4,200 m/min under relaxing conditions to provide nylon 66 fiber of 40 dtex/98 filaments and 45% elongation percentage. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 1. In Tables, nylon 66 is abbreviated as N66.

Example 2

[0063] Except that a nylon 6 material with a 98% sulfuric acid relative viscosity of 2.63 was melted at 255°C, and fed to a melt-spinning pack, the same spinning procedure as in Example 1 was carried out to provide nylon 6 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 1. In Tables, nylon 6 is abbreviated as N6.

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Example 3

[0064] Except for using an spinneret provided with 268 circular holes, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/268 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 1.

Example 4

[0065] Except for using an spinneret provided with 82 circular holes, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/82 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 1.

Example 5

[0066] Except that the cooling air blow-out portion of the outward blow type circular cooling apparatus installed on the downstream side of the steam blow-out zone under the spinneret had a vertical length of 100 mm and that a finishing oil was supplied by the circular finishing oil supply apparatus at a position 300 mm below the spinneret, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 1.

Example 6

[0067] Except that a nylon 66 material with a 98% sulfuric acid relative viscosity of 2.63 was melted at 275°C, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 1.

[0068] [Table 1]

Table 1

Item	Unit	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
Total fineness	dtex	40	40	40	40	40	40
Filament number	-	98	98	268	82	98	98
Single yarn fineness	dtex	0.41	0.41	0.15	0.49	0.41	0.41
Cross section shape	-	circular	circular	circular	circular	circular	circular
Polymer	-	N66	N6	N66	N66	N66	N66
Cooling apparatus	-	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus
Polymer temperature	°C	285°C	255°C	285°C	285°C	285°C	275°C
Spinneret-cooling apparatus distance	mm	30 mm	30 mm	30 mm	30 mm	30 mm	30mm
Cooling air speed	m/min	40 m/min	40 m/min	40 m/min	40 m/min	40 m/min	40 m/min

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(continued)

Item	Unit	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
Cooling air supply length	mm	300 mm	300 mm	300 mm	300 mm	100 mm	300 mm
The take-up speed	m/min	4000	4000	4000	4000	4000	4000
Draw ratio	-	1.10	1.10	1.10	1.10	1.10	1.10
Finishing oil supply apparatus 1	-	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus
Finishing oil supply apparatus 2	-	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus
Uster unevenness	%	0.49	0.80	0.98	0.39	0.97	0.54
Average number of fuzzes	/ 12,000m	0.0	0.0	0.8	0.0	0.2	0.9
Orientation parameter ratio	-	1.26	1.32	1.66	1.14	1.24	1.29
Stress at 15% elongation	gf/dtex (N/dtex)	1.30 (12.7×10 ⁻³)	1.35 (13.2×10 ⁻³)	1.70 (16.7×10 ⁻³)	1.21 (11.9×10 ⁻³)	1.32 (12.9×10 ⁻³)	1.29 (12.6×10 ⁻³)
Softness of cloth	(A) to (D)	(A)	(B)	(A)	(B)	(A)	(A)
Dyeing quality of cloth	(A) to (D)	(A)	(A)	(C)	(A)	(C)	(C)
Water absorption capacity of cloth	(A) to (D)	(B)	(B)	(A)	(C)	(B)	(B)
Anti-see-through property of cloth	(A) to (D)	(B)	(B)	(A)	(C)	(B)	(B)
Overall evaluation of cloth	(A) to (D)	(A)	(B)	(B)	(c)	(B)	(B)

Example 7

[0069] Except that an spinneret provided with 42 circular holes was used and that the fineness was 17 dtex, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 17 dtex/42 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 2.

Example 8

[0070] Except that an spinneret provided with 680 circular holes was used and that the fineness was 280 dtex, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 280 dtex/680 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 2.

Example 9

[0071] Except that an spinneret provided with 32 circular holes was used and that the fineness was 15 dtex, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 15 dtex/32 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 2.

Example 10

[0072] Except that a nylon 6 material with a 98% sulfuric acid relative viscosity of 2.63 was melted at 255°C, fed to a melt-spinning pack, and discharged from an spinneret provided with 98 discharge holes each having a slit with a trilobal cross section as shown in Fig. 2, the same spinning procedure as in Example 1 was carried out to provide nylon 6 fiber of 40 dtex/98 filaments having a trilobal cross section. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 2.

Example 11

[0073] Except for using a 98-hole spinneret provided with 49 discharge holes each having a hexalobal cross section as shown in Fig. 3 and the same number of coexisting circular holes, the same spinning procedure as in Example 10 was carried out to provide nylon 6 fiber of 40 dtex/98 filaments in which hexalobal and circular cross sections coexist. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 2.

[0074] [Table 2]

Table 2

Item	Unit	Example 7	Example 8	Example 9	Example 10	Example 1
Total fineness	dtex	17	280	15	40	40
Filament number	-	42	680	32	98	98
Single yarn fineness	dtex	0.40	0.41	0.47	0.41	circular 0.39 / hexalobal 0.42
Cross section shape	-	circular	circular	circular	trilobal	circular/ hexalobal combined
Polymer	-	N66	N66	N66	N6	N6
Cooling apparatus	-	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus
Polymer temperature	°C	285°C	285°C	285°C	255°C	255°C
Spinneret-cooling apparatus distance	mm	30 mm	30 mm	30 mm	30 mm	30 mm
Cooling air speed	m/min	40m/min	40 m/min	40m/min	40m/min	40 m/min
Cooling air supply length	mm	300 mm	300 mm	300 mm	300 mm	300 mm

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(continued)

Item	Unit	Example 7	Example 8	Example 9	Example 10	Example 1
The take-up speed	m/min	4000	4000	4000	4000	4000
Draw ratio	-	1.10	1.10	1.10	1.10	1.10
Finishing oil supply apparatus 1	-	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus
Finishing oil supply apparatus 2	-	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus
Uster unevenness	%	0.47	0.88	0.42	0.91	0.85
Average number of fuzzes	/12,000m	0.0	0.8	0.0	0.3	0.0
Orientation parameter ratio	-	1.26	1.20	1.31	-	1.33 (circular cross section)
Stress at 15% elongation	gf/dtex (N/dtex)	1.25 (12.3×10^{-3})	1.30 (12.7×10^{-3})	1.31 (12.8×10^{-3})	1.50 (14.7×10^{-3})	1.41 (13.8×10^{-3})
Softness of cloth	(A) to (D)	(B)	(A)	(B)	(B)	(B)
Dyeing quality of cloth	(A) to (D)	(B)	(C)	(A)	(C)	(B)
Water absorption capacity of cloth	(A) to (D)	(C)	(B)	(B)	(A)	(A)
Anti-see-through property of cloth	(A) to (D)	(B)	(B)	(C)	(A)	(A)
Overall evaluation of cloth	(A) to (D)	(B)	(B)	(B)	(B)	(A)

Example 12

[0075] Except that the yarns were interlaced first, taken up at 3,000 m/min, drawn at a draw ratio of 1.50, and wound up at 4,300 m/min under relaxing conditions, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 3.

Example 13

[0076] Except for passing the yarns through a stand-alone, inward blow type circular cooling apparatus provided with a cooling air supply portion with a vertical length of 300 mm instead of an outward blow type circular cooling apparatus, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The

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resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 3.

Example 14

[0077] Except that the cooling start distance was 20 mm, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 3.

Example 15

[0078] Except that the cooling start distance was 40 mm, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 3.

Example 16

[0079] Except that the cooling start distance was 10 mm, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 3.

[0080] [Table 3]

Table 3

Item	Unit	Example 12	Example 13	Example 14	Example 15	Example 16
Total fineness	dtex	40	40	40	40	40
Filament number	-	98	98	98	98	98
Single yarn fineness	dtex	0.41	0.41	0.41	0.41	0.41
Cross section shape	-	circular	circular	circular	circular	circular
Polymer	-	N66	N66	N66	N66	N66
Cooling apparatus	-	outward blow type circular cooling apparatus	inward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus
Polymer temperature	°C	285°C	285°C	285°C	285°C	285°C
Spinneret-cooling apparatus distance	mm	30 mm	30mm	20 mm	40mm	10 mm
Cooling air speed	m/min	40 m/min	40 m/min	40 m/min	40 m/min	40 m/min
Cooling air supply length	mm	300 mm	300 mm	300 mm	300 mm	300 mm
The take-up speed	m/min	3000	4000	4000	4000	4000
Draw ratio	-	1.50	1.10	1.10	1.10	1.10

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(continued)

Item	Unit	Example 12	Example 13	Example 14	Example 15	Example 16
Finishing oil supply apparatus 1	-	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus
Finishing oil supply apparatus 2	-	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus
Uster unevenness	%	0.45	0.56	0.46	0.56	0.45
Average number of fuzzes	/12,000m	0.9	0.5	0.1	0.0	0.6
Orientation parameter ratio	-	1.12	1.19	1.31	1.15	1.34
Stress at 15% elongation	gf/dtex (N/dtex)	1.50 (14.7×10^{-3})	1.31 (12.8×10^{-3})	1.31 (12.8×10^{-3})	1.28 (12.5×10^{-3})	1.33 (13.0×10^{-3})
Softness of cloth	(A) to (D)	(B)	(A)	(A)	(A)	(A)
Dyeing quality of cloth	(A) to (D)	(B)	(B)	(B)	(A)	(C)
Water absorption capacity of cloth	(A) to (D)	(B)	(B)	(B)	(B)	(B)
Anti-see-through property of cloth	(A) to (D)	(C)	(B)	(A)	(B)	(A)
Overall evaluation of cloth	(A) to (D)	(B)	(B)	(A)	(A)	(B)

Example 17

[0081] Except that the cooling start distance was 60 mm, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 4.

Example 18

[0082] Except that the flow speed of the cooling air at 20°C sent radially outward from the outward blow type circular cooling apparatus was 27 m/min, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 4.

Example 19

[0083] Except that the flow speed of the cooling air at 20°C sent radially outward from the outward blow type circular

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cooling apparatus was 49 m/min, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 4.

Example 20

[0084] Except that the flow speed of the cooling air at 20°C sent radially outward from the outward blow type circular cooling apparatus was 17 m/min, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 4.

Example 21

[0085] Except that the flow speed of the cooling air at 20°C sent radially outward from the outward blow type circular cooling apparatus was 58 m/min, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 4.

[0086] [Table 4]

Table 4

Item	Unit	Example 17	Example 18	Example 19	Example 20	Example 21
Total fineness	dtex	40	40	40	40	40
Filament number	-	98	98	98	98	98
Single yarn fineness	dtex	0.41	0.41	0.41	0.41	0.41
Cross section shape	-	circular	circular	circular	circular	circular
Polymer	-	N66	N66	N66	N66	N66
Cooling apparatus	-	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus
Polymer temperature	°C	285°C	285°C	285°C	285°C	285°C
Spinneret-cooling apparatus distance	mm	60 mm	30 mm	30 mm	30 mm	30 mm
Cooling air speed	m/min	40 m/min	27 m/min	49m/min	17m/min	58 m/min
Cooling air supply length	mm	300 mm	300 mm	300 mm	300 mm	300 mm
The take-up speed	m/min	4000	4000	4000	4000	4000
Draw ratio	-	1.10	1.10	1.10	1.10	1.10
Finishing oil supply apparatus 1	-	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus	circular finishing oil supply apparatus

(continued)

Item	Unit	Example 17	Example 18	Example 19	Example 20	Example 21
Finishing oil supply apparatus 2	-	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus
Uster unevenness	%	0.97	0.70	0.65	0.99	0.89
Average number of fuzzes	/12,000m	0.1	0.0	0.2	0.4	0.7
Orientation parameter ratio	-	1.13	1.19	1.27	1.15	1.30
Stress at 15% elongation	gf/dtex (N/dtex)	1.25 (12.2×10 ⁻³)	1.32 (12.9×10 ⁻³)	1.31 (12.8×10 ⁻³)	1.36 (13.3×10 ⁻³)	1.33 (13.0×10 ⁻³)
Softness of cloth	(A) to (D)	(A)	(A)	(A)	(A)	(A)
Dyeing quality of cloth	(A) to (D)	(C)	(A)	(B)	(C)	(C)
Water absorption capacity of cloth	(A) to (D)	(B)	(B)	(B)	(B)	(B)
Anti-see-through property of cloth	(A) to (D)	(C)	(B)	(A)	(C)	(A)
Overall evaluation of cloth	(A) to (D)	(C)	(A)	(A)	(C)	(B)

Comparative example 1

[0087] Except that yarns were discharged from a spinneret provided with 160 circular holes and that the fineness was 15 dtex, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 15 dtex/160 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 5.

Comparative example 2

[0088] Except that the fineness was 56 dtex, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 56 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 5.

Comparative example 3

[0089] Except that a disk-like guide that did not have a finishing oil-discharging circular slit was provided at a position 500 mm from the spinneret face located vertically below the outward blow type circular cooling apparatus and that finishing oil supply was not performed for the single yarns that were maintained in contact with the disk-like guide, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 5.

Comparative example 4

[0090] Except that polyethylene terephthalate resin was melted at 290°C and then fed to a melt-spinning pack, the same spinning procedure as in Example 1 was carried out to provide polyethylene terephthalate fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 5.

Comparative example 5

[0091] Except that a unidirectional type uniflow chimney was used as the cooling apparatus and that the yarns were bundled and lubricated by a finishing oil supply guide, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 5.

Comparative example 6

[0092] Except that a finishing oil was supplied by a circular finishing oil supply apparatus and then the yarns were bundled without being subjected to a second-stage finishing oil supply, the same spinning procedure as in Example 1 was carried out to provide nylon 66 fiber of 40 dtex/98 filaments. The resulting raw yarn and cloth were subjected to characteristics evaluation. Results are given in Table 5.

[0093] [Table 5]

Table 5

Item	Unit	Comparative example 1	Comparative example 2	Comparative example 3	Comparative example 4	Comparative example 5	Comparative example 6
Total fineness	dtex	15	56	40	40	40	40
Filament number	-	160	98	98	98	98	98
Single yarn fineness	dtex	0.09	0.57	0.41	0.41	0.41	0.41
Cross section shape	-	circular	circular	circular	circular	circular	circular
Polymer	-	N66	N66	N66	PET	N66	N66
Cooling apparatus	-	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	outward blow type circular cooling apparatus	uniflow chimney	outward blow type circular cooling apparatus
Polymer temperature	°C	285°C	285°C	285°C	290°C	285°C	285°C
Spinneret-cooling apparatus distance	mm	30 mm	30 mm	30 mm	30 mm	30 mm	30 mm
Cooling air speed	m/min	40 m/min	40 m/min	40 m/min	40 m/min	40 m/min	40 m/min
Cooling air supply length	mm	300 mm	300 mm	300 mm	300 mm	300 mm	300 mm
The take-up speed	m/min	4000	4000	4000	4000	4000	4000
Draw ratio		1.10	1.10	1.10	1.10	1.10	1.10
Finishing oil supply apparatus 1	-	circular finishing oil supply apparatus	circular finishing oil supply apparatus	contact with circular without finishing oil supply	circular finishing oil supply apparatus	-	circular finishing oil supply apparatus
Finishing oil supply apparatus 2	-	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	bundle-guide type finishing oil supply apparatus	yarns bundled without finishing oil supply
Uster unevenness	%	1.20	0.38	0.88	0.31	3.10	1.11

(continued)

Item	Unit	Comparative example 1	Comparative example 2	Comparative example 3	Comparative example 4	Comparative example 5	Comparative example 6
Average number of fuzzes	/12,000m	2.0	0.0	1.3	0.0	7.2	1.2
Orientation parameter ratio	-	1.90	1.07	1.24	1.85	1.01	1.25
Stress at 15% elongation	gf/dtex (N/dtex)	1.50 (14.7×10 ⁻³)	1.27 (12.4×10 ⁻³)	1.31 (12.8×10 ⁻³)	1.45 (14.2×10 ⁻³)	1.81 (17.7×10 ⁻³)	1.30 (12.7×10 ⁻³)
Softness of cloth	(A) to (D)	(A)	(C)	(A)	(D)	(A)	(A)
Dyeing quality of cloth	(A) to (D)	(D)	(A)	(D)	(B)	(D)	(D)
Water absorption capacity of cloth	(A) to (D)	(B)	(C)	(B)	(D)	(B)	(B)
Anti-see-through property of cloth	(A) to (D)	(A)	(D)	(B)	(A)	(D)	(B)
Overall evaluation of cloth	(A) to (D)	(D)	(D)	(D)	(D)	(D)	(D)

Explanation of numerals

[0094]

- 5 1. spinneret
2. heat retaining zone under spinneret
3. outward blow type circular cooling apparatus
4. circular finishing oil supply apparatus
5. bundle-guide type finishing oil supply apparatus
- 10 6. interlacing nozzle
7. take-up roller
8. drawing roller
9. winder (wind-up apparatus)
10. fiber filament
- 15 11. fiber product package
12. finishing oil-discharging slit
13. disk-like guide
14. fiber filament
15. finishing oil pool
- 20 16. finishing oil discharged from slit
17. finishing oil feed pipe
18. inward blow type circular cooling apparatus

25 Claims

1. Ultrafine polyamide fiber comprising polyamide fiber with a single yarn fineness of 0.10 dtex or more and 0.50 dtex or less, the average number of fuzzes being 1.0 or less per 12,000 m of a filament in the length direction.
- 30 2. Ultrafine polyamide fiber as defined in claim 1 wherein the Uster unevenness in a filament in the length direction is 1.0% or less.
3. Ultrafine polyamide fiber as defined in either claim 1 or 2 having a total fineness of 15 to 300 dtex and containing 30 or more filaments.
- 35 4. Ultrafine polyamide fiber as defined in any of claims 1 to 3 wherein filaments have a modified cross section.
5. Ultrafine polyamide fiber as defined in any of claims 1 to 3 wherein the single yarns contained in the ultrafine polyamide fiber have a circular filament cross section, the orientation parameters of the single yarns with a circular cross section being such that the ratio of the orientation parameter of the surface portion of the single yarn to the orientation parameter of the central portion of the single yarn is 1.10 or more.
- 40 6. A melt-spinning method for ultrafine polyamide fiber having a single yarn fineness of 0.10 dtex or more and 0.50 dtex or less and having an average of 1.0 or less fuzzes per 12,000 m in the length direction, wherein melt-spun yarns discharged from a spinning spinneret provided with discharge holes arranged circumferentially in the outer circumferential portion of the spinning spinneret are cooled by a cooling apparatus located below the central portion of the spinning spinneret and designed to cool the melt-spun yarns by applying cooling air from either inside or outside of the melt-spun yarns discharged from the discharge holes, a finishing oil being supplied by a circular finishing oil supply apparatus having a disk-like guide portion that is located vertically below the cooling apparatus and that is in contact with the single yarns at its outer circumferential portion and also having a circular finishing oil-discharging slit that is located directly above the guide portion and arranged along the outer circumference of the guide, and subsequently the yarns being bundled by a bundle-guide type finishing oil supply apparatus while receiving a second-stage finishing oil supply.
- 50 7. The melt-spinning method for ultrafine polyamide fiber as defined in claim 6 wherein the cooling apparatus is designed to cool the melt-spun yarns by supplying cooling air from inside of the melt-spun yarns discharged from the discharge holes.
- 55

8. The melt-spinning method for ultrafine polyamide fiber as defined in either claim 6 or 7 wherein the cooling apparatus meets the following requirements:

(1) the distance (L) from the face of the spinning spinneret to the cooling start position of the cooling apparatus is as follows: $10 \text{ mm} \leq L \leq 70 \text{ mm}$, and
 (2) the cooling air provided at the cooling start position has a flow speed of 15 to 60 m/min.

9. A melting spinning apparatus that is designed for ultrafine polyamide fiber having a single yarn fineness of 0.10 dtex or more and 0.50 dtex or less and having an average of 1.0 or less fuzzes per 12,000 m in the length direction, and that comprises a spinning spinneret provided with discharge holes arranged circumferentially in the outer circumferential portion of the spinning spinneret, and a cooling apparatus located below the central portion of the spinning spinneret and intended to cool the melt-spun yarns by applying cooling air from inside or outside of the melt-spun yarns discharged from the discharge holes, and further comprises a circular finishing oil supply apparatus having a disk-like guide portion that is located vertically below the cooling apparatus and that is in contact with the single yarns at its outer circumferential portion and also having a circular finishing oil-discharging slit that is located directly above the guide portion and arranged along the outer circumference of the guide, as well as a bundle-guide type finishing oil supply apparatus located thereunder and intended to bundle the yarns while performing a second-stage finishing oil supply.

10. The melt-spinning apparatus for ultrafine polyamide fiber as defined in claim 9 wherein the cooling apparatus is designed to cool the melt-spun yarns by supplying cooling air from inside of the melt-spun yarns discharged from the discharge holes.

Figure 1

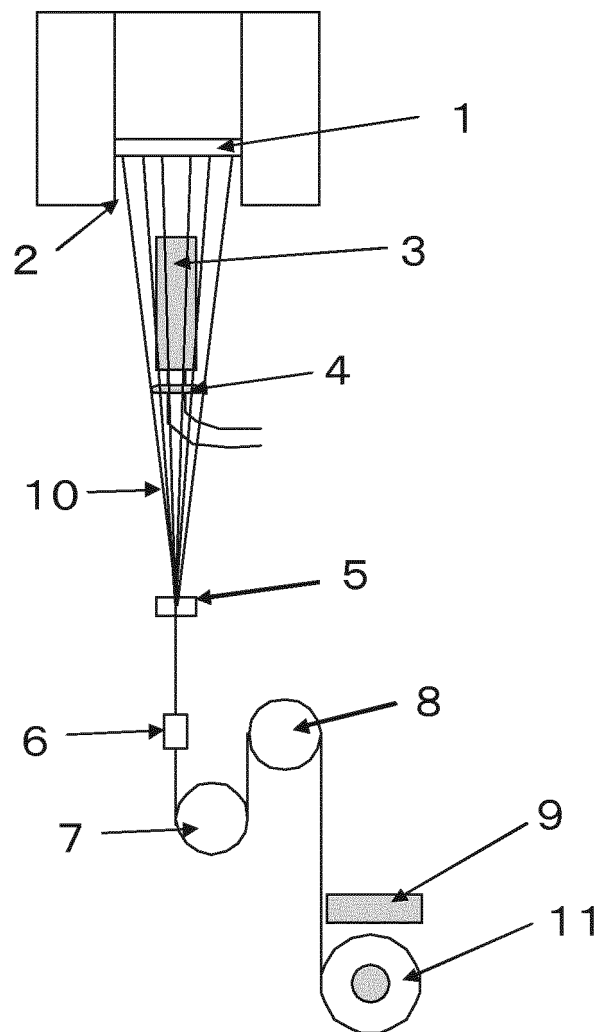


Figure 2

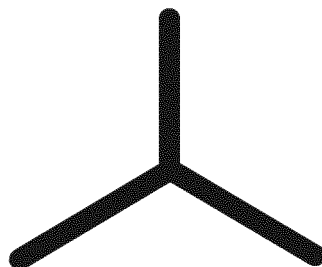


Figure 3

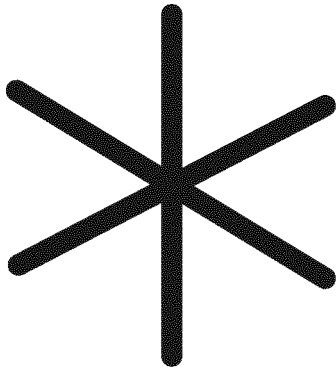


Figure 4

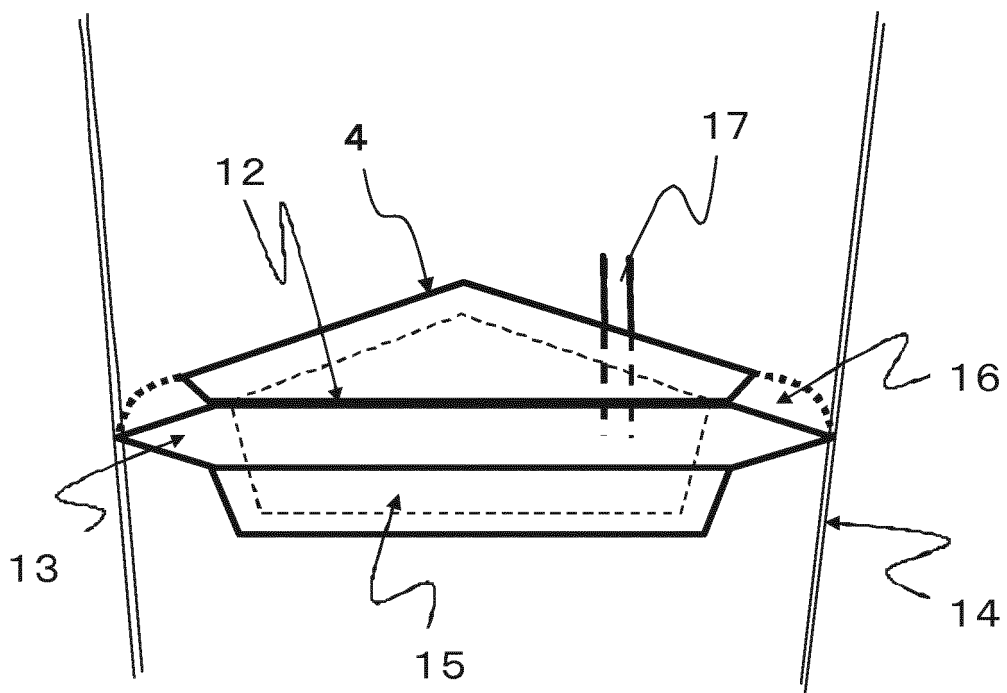
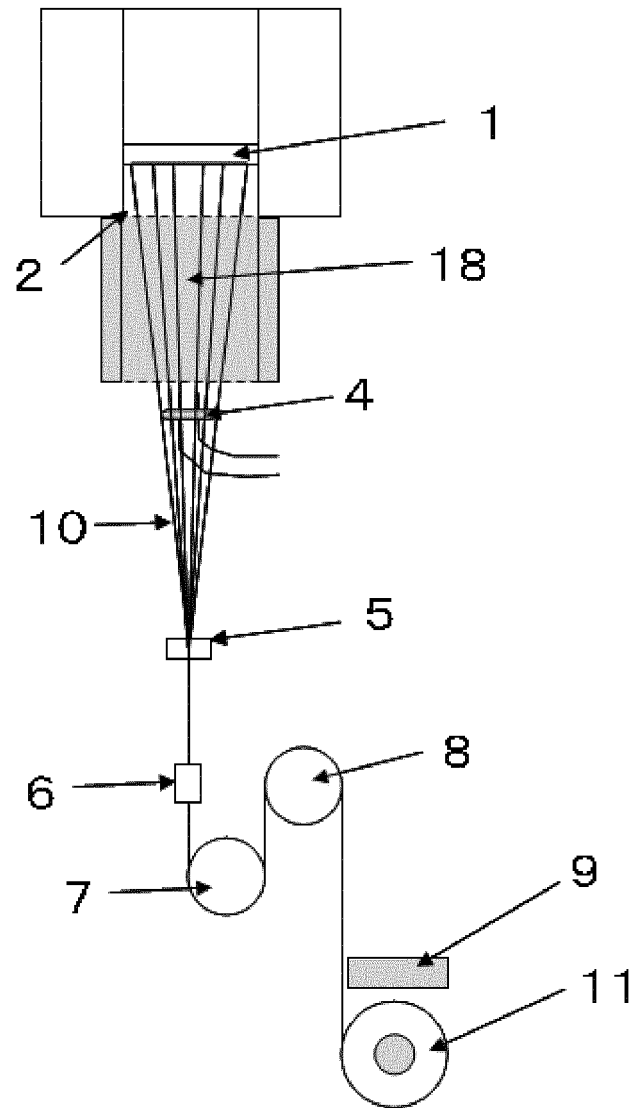


Figure 5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/076780

A. CLASSIFICATION OF SUBJECT MATTER

D01F6/60 (2006.01) i, D01D5/092 (2006.01) i, D01D5/096 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D01D1/00-13/02, D01F1/00-6/96, D01F9/00-9/04, D01F11/00-11/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2010-126846 A (Toray Industries, Inc.), 10 June 2010 (10.06.2010), paragraphs [0012] to [0017], [0022]; examples 1, 2; table 1; fig. 3, 4 (Family: none)	1-10
A	JP 2007-77547 A (Toray Industries, Inc.), 29 March 2007 (29.03.2007), claims; examples 1 to 6; drawings (Family: none)	1-10
A	JP 2010-77570 A (Toray Industries, Inc.), 08 April 2010 (08.04.2010), paragraphs [0014], [0015]; drawings (Family: none)	1-10

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05 January, 2012 (05.01.12)Date of mailing of the international search report
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A	JP 2011-74539 A (Toray Industries, Inc.), 14 April 2011 (14.04.2011), claims; paragraphs [0043] to [0046]; fig. 3, 4 (Family: none)	1-10

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2009084749 A [0006]
- JP 2007126759 A [0006]
- JP 2010126846 A [0006]