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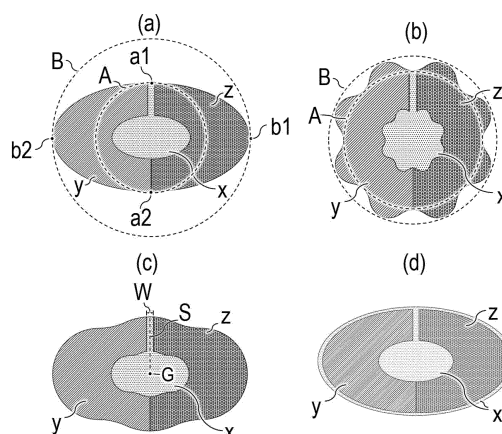
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(54) **COMPOSITE FIBER, HOLLOW FIBER AND MULTIFILAMENT**

(57) The present invention relates to a composite fiber wherein: two or more kinds of polymers, which are different from each other in the dissolution rate in a solvent, are stacked from the center of the fiber in the direction toward the fiber surface in a cross-section of the fiber; the innermost layer comprising the center of the fiber contains an easily soluble polymer; and two or more kinds of poorly soluble polymers, which have different melting points, are unevenly distributed in at least one layer other than the innermost layer. The present invention also relates to a multifilament which contains a flat hollow fiber, wherein the coefficient of variation CV of the rotation angle of the major axis of the flat hollow fiber is from 15% to 50%.

FIG. 3



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a composite fiber, a hollow fiber, and a multifilament, which are suitable for a clothing textile excellent in wearing comfort.

BACKGROUND ART

10 **[0002]** A synthetic fiber made of polyester, polyamide, or the like has excellent mechanical properties and dimensional stability, and thus is widely used from clothing applications to non-clothing applications. However, in recent years, when lives of people diversify and people have come to seek a better life, there is a demand for a fiber having higher tactile sensations and functions.

15 **[0003]** Among these, in a clothing textile in contact with human skin, excellent wearing comfort is often required, and particularly, there is a strong demand for a fiber having a texture directly linked to wearing comfort of a human, such as a natural fiber. This is because a texture and a function of a natural fiber such as linen, wool, cotton, and silk are very well balanced, and a complex appearance and a tactile sensation formed by these fibers are attractive and luxurious to humans.

20 **[0004]** As an example of a technique aiming to achieve a comfortable texture achieved by such a natural fiber, various techniques have been proposed in which a cross section of the synthetic fiber is devised to form a void structure in which air is enclosed in a fabric, thereby developing moderate resilience and a puffy and soft texture.

25 **[0005]** Patent Literature 1 proposes a hollow fiber having a flattened hollow cross-sectional shape and a twisted structure which are similar to cotton, obtained by subjecting a hollow fiber obtained using a spinneret for hollowing to a false twisting process to impart a crimp and at the same time deforming and flattening a hollow cross section. Patent Literature 1 describes that such a flat hollow fiber can provide a puffy or resilient texture like the cotton.

30 **[0006]** Patent Literature 2 proposes a hollow fiber having a C-shaped cross-sectional shape including a hollow portion and an opening portion which are continuous in a fiber axis direction, obtained by subjecting, to a false twisting process, a core-sheath composite fiber including an easily alkali-soluble polymer as a core component and a hardly alkali-soluble polymer as a sheath component, with a part of the core component exposed on a fiber surface, and then eluting the core component by an alkali treatment. Patent Literature 2 describes that when the core-sheath composite fiber is formed into a woven or knitted fabric, it is possible to impart a soft texture or the like while having a lightweight feel and moderate resilience due to an effect of a C-shaped hollow.

35 **[0007]** Patent Literature 3 proposes a high bulk lightweight multifilament having a fiber cross section in which two or more kinds of polymers having different dissolution rates in a solvent are laminated in a cross-sectional direction to form an outermost layer, an intermediate layer, and an innermost layer, the polymer forming the outermost layer and the innermost layer is an easily soluble polymer, and two or more kinds of single-yarns having different cross-sectional shapes in the intermediate layer are mixed. In the high bulk lightweight multifilament, not only an inside of a fiber but also a fiber surface are made of the easily soluble polymer, whereby voids can be formed inside and outside the fiber after the easily soluble polymer is eluted, and further, since different fiber cross sections are mixed after the elution, collapse of inter-fiber voids is prevented, and a fabric having a soft texture in addition to a lightweight feel and a puffy feel can be obtained.

CITATION LIST

45 PATENT LITERATURE

[0008]

50 Patent Literature 1: JPS54-151650A
 Patent Literature 2: JPH01-05283 9A
 Patent Literature 3: JP2019-167646A

SUMMARY OF INVENTION

55 TECHNICAL PROBLEM

[0009] If a void structure can be imparted to an inside and outside of the fiber by subjecting the hollow fiber to the false twisting process as in Patent Literature 1, there is a possibility that the texture like the cotton which is the natural

fiber can be reproduced to some extent. However, in Patent Literature 1, a technical idea is that the fibers are densely bundled by the false twisting process and deformed while hollow portions are crushed, and in some cases, the puffy or resilient texture that is comfortable when the fibers are worn as clothes is lacking.

[0010] As in Patent Literature 2, in a method in which the core-sheath composite fiber containing the easily alkali-soluble polymer as the core component and the hardly alkali-soluble polymer as the sheath component is subjected to the false twisting process, since the core component can be eluted and the hollow portion can be formed by performing the alkali treatment after weaving and knitting, the hollow portion is not crushed by the false twisting process, and inter-fiber voids can be formed by a high hollow ratio and a crimped form. However, in order to prevent elution unevenness of the core component, the C-shaped cross-sectional shape having the large opening portion is used, and the adjacent fibers get caught in the opening portion, which not only makes the texture hard, but also may reduce the lightweight feel and the resilience with continued use.

[0011] Further, Patent Literature 1 and Patent Literature 2 both use the false twisting process in which a multifilament is heat-set in a twisted state and then untwisted to impart a crimp. Therefore, crimping tends to be less resilient due to a heat treatment at the time of high-order processing, and the puffy texture which is comfortable when the fibers are worn as the clothes may be lacking. Further, since the crimps of the respective fibers in the multifilament are uniform, the texture obtained in the textile is also monotonous, and in order to achieve a complicated texture such as a natural fiber, it is necessary to perform advanced weaving and knitting, and to mix the fibers with other materials including the natural fiber.

[0012] On the other hand, as in Patent Literature 3, a method of utilizing the inter-fiber voids formed by eluting fiber surfaces is effective from the viewpoint of flexibility, but there is a limit in an effect of preventing the collapse of the inter-fiber voids obtained by mixing the different fiber cross sections, and it is difficult to say that coarse inter-fiber voids are developed to the extent that the puffy texture is felt.

[0013] Therefore, an object of the present invention is to solve the above-described problems of background art, and to provide a composite fiber, a hollow fiber, and a multifilament which are suitable for obtaining a textile having moderate resilience and a puffy and soft texture and excellent in wearing comfort by controlling void structures inside and between fibers.

SOLUTION TO PROBLEM

[0014] An object of the present invention can be achieved by the following configurations.

(1) A composite fiber including:

two or more kinds of polymers that have different dissolution rates in a solvent and are laminated in a direction from a fiber center to a fiber surface in a fiber cross section, in which an innermost layer including the fiber center includes an easily soluble polymer, and two kinds of hardly soluble polymers having different melting points are unevenly distributed in at least one layer other than the innermost layer.

(2) The composite fiber according to (1), in which a relationship between an inscribed circle diameter RA and a circumscribed circle diameter RB of the fiber is $1.2 \leq RB/RA \leq 2.4$ in the fiber cross section.

(3) The composite fiber according to (1) or (2), in which in the fiber cross section, the easily soluble polymer communicates from the fiber center to the fiber surface, and a communication width is 10% or less of a fiber diameter.

(4) The composite fiber according to any one of (1) to (3), in which in the fiber cross section, an outermost layer includes the easily soluble polymer.

(5) A hollow fiber obtained by removing the easily soluble polymer from the composite fiber according to any one of (1) to (4).

(6) A multifilament includes:

a flat hollow fiber, in which a variation coefficient CV of a rotation angle of a long axis of the flat hollow fiber is 15% to 50%.

(7) The multifilament according to (6), in which the flat hollow fiber has a flatness of 1.2 or more in a fiber cross section.

(8) The multifilament according to (6) or (7), in which the flat hollow fiber is made of at least two kinds of polymers having different melting points in a fiber cross section.

(9) The multifilament according to any one of (6) to (8), in which

the flat hollow fiber includes an opening portion formed in a direction from a fiber center to a fiber surface, and a width of the opening portion is 10% or less of a fiber diameter.

(10) A fiber product partially including:

the composite fiber according to any one of (1) to (4), the hollow fiber according to (5), or the multifilament according to any one of (6) to (9).

ADVANTAGEOUS EFFECTS OF INVENTION

[0015] A composite fiber, a hollow fiber, and a multifilament according to the present invention have the above-described features, whereby void structures inside and between the fibers are finely controlled, and it is possible to obtain a textile excellent in wearing comfort, which achieves moderate resilience and a puffy and soft texture.

BRIEF DESCRIPTION OF DRAWINGS

[0016]

[FIG. 1] (a), (b), (c), and (d) of FIG. 1 are schematic views of cross-sectional structures of a composite fiber according to the present invention.

[FIG. 2] (a), (b), and (c) of FIG. 2 are schematic views of cross-sectional structures of the composite fiber according to the present invention.

[FIG. 3] (a), (b), (c), and (d) of FIG. 3 are schematic views of cross-sectional structures of the composite fiber according to the present invention.

[FIG. 4] (a) and (b) of FIG. 4 are schematic views of cross-sectional structures of a composite fiber in background art.

[FIG. 5] FIG. 5 shows schematic views of cross-sectional structures of a multifilament according to the present invention. (a) of FIG. 5 is a view illustrating flatness. (b) of FIG. 5 is a view illustrating a variation coefficient CV of a rotation angle of a long axis of a fiber in the multifilament, and broken lines in an outer frame mean top, bottom, left, and right sides of a captured image.

[FIG. 6] (a), (b), and (c) of FIG. 6 are schematic views of cross-sectional structures of a fiber constituting the multifilament according to the present invention.

[FIG. 7] (a) of FIG. 7 is a schematic view of a cross-sectional structure of a fiber constituting the multifilament in Example 6. (b) of FIG. 7 is a schematic view of a cross-sectional structure of a fiber constituting a multifilament in Example 2.

[FIG. 8] FIG. 8 is a schematic view of a cross-sectional structure of a fiber constituting a multifilament in Comparative Example 3.

[FIG. 9] FIG. 9 shows schematic views of cross-sectional structures of the fiber constituting the multifilament according to the present invention.

[FIG. 10] FIG. 10 shows schematic views of cross-sectional structures of an example of a composite fiber from which the multifilament according to the present invention can be produced.

[FIG. 11] FIG. 11 shows an example of a crimped form of the fiber constituting the multifilament according to the present invention.

[FIG. 12] FIG. 12 is a cross-sectional view illustrating a method for producing the composite fiber according to the present invention.

DESCRIPTION OF EMBODIMENTS

[0017] Hereinafter, the present invention will be described in detail together with preferred embodiments.

[0018] When a void structure of cotton widely spread as a natural material having a puffy and soft texture is analyzed, it can be seen that inter-fiber voids of large and small sizes are present in addition to presence of a hollow portion in a flat fiber. This is derived from the fact that each fiber is twisted in the cotton, and it is considered that by bundling a plurality of fibers which are twisted, complicated voids and irregularities are formed when the fibers are made into a textile, and a specific tactile sensation or texture is produced.

[0019] In order to achieve formation of such complicated voids peculiar to nature, the present inventors have conducted extensive studies, and have found that when a crimped form is developed in the fiber after high-order processing such as weaving and knitting is performed, a plurality of fibers gathered in a fabric are twisted to develop the inter-fiber voids of various sizes in large and small sizes. Furthermore, a basis of the present invention is that by eluting an easily soluble

polymer inside the fiber to form the hollow portion inside the fiber, it is possible to obtain a complicated void structure that has been difficult to obtain with a synthetic fiber of background art or a textured yarn using the same, whereby moderate resilience and a puffy and soft texture that has not been achieved so far has been achieved.

[0020] Specifically, a requirement of the present invention is that, in a fiber cross section, two or more kinds of polymers having different dissolution rates in a solvent are laminated in a direction from a fiber center to a fiber surface, an innermost layer including the fiber center includes the easily soluble polymer, and two kinds of hardly soluble polymers having different melting points are unevenly distributed in at least one layer other than the innermost layer.

[0021] In the present invention, a polymer having a relatively high dissolution rate with respect to a solvent used for a dissolution treatment is referred to as an easily soluble polymer, and a polymer having a low dissolution rate is referred to as a hardly soluble polymer. In consideration of simplification of the dissolution treatment and reduction in time in the high-order processing, a dissolution rate ratio (easily soluble polymer/hardly soluble polymer) based on the hardly soluble polymer is preferably 100 or more, and more preferably 1,000 or more. When the dissolution rate ratio is 1,000 or more, the dissolution treatment can be completed in a short time, and therefore, in addition to increasing a process speed, a fabric having high quality can be obtained without unnecessarily deteriorating the hardly soluble polymer.

[0022] In a composite fiber according to the present invention, in order to stably form the hollow portion inside the fiber without being influenced by a structure which is woven, knitted, or the like, it is necessary that two or more kinds of polymers having different dissolution rates in the solvent are laminated in the fiber cross section in a direction from the fiber center to the fiber surface, and the innermost layer including the fiber center includes the easily soluble polymer. The innermost layer is preferably made of the easily soluble polymer.

[0023] Since the hollow portion is stably formed inside the fiber when the composite fiber is made into a textile, a puffy or lightweight feel of the textile is improved, and since an air layer is present inside the fiber, each fiber can be flexibly deformed while having the moderate resilience, whereby the moderate resilience and the puffy and soft texture, which is an object of the present invention, can be obtained.

[0024] Furthermore, as a hollow ratio inside the fiber increases, a lightweight feel and flexibility are remarkably improved, and in the composite fiber according to the present invention, an area ratio of the innermost layer including the fiber center is preferably 10% or more, and more preferably 20% or more. A higher area ratio of the innermost layer is preferable from the viewpoint of lightness, but a substantial upper limit of the area ratio is 50% since excessive elution of the innermost layer may reduce strength or cause the hollow portion to be easily crushed, thereby impairing the resilience.

[0025] In the composite fiber according to the present invention, it is important that the fiber develops the crimped form after being subjected to the high-order processing such as weaving and knitting. When the fibers in the fabric are crimped and twisted, the adjacent fibers and the crimped forms are intertwined with each other, so that the inter-fiber voids of various sizes can be developed, whereby the moderate resilience and the puffy and soft texture can be developed when the composite fiber is made into the textile, and functions such as a water-absorbing quick-drying property due to a capillary phenomenon of the fine inter-fiber voids and stretchability due to the coiled crimped form can be developed.

[0026] In order to develop the crimped form in the fiber after performing the high-order processing such as weaving and knitting, a composite cross section having a latent crimping property in which crimping is developed by a heat treatment may be used, and by disposing polymers having different differential shrinkage in the fiber cross section such that centers of gravity thereof are different from each other, the fiber is largely curved toward a highly shrinkable polymer side after the heat treatment, and by continuing this, a three-dimensional spiral structure is formed.

[0027] That is, in order to achieve an object of the present invention, it is important to dispose the polymers having different differential shrinkage in the fiber cross section so as to maintain a sufficient distance between the centers of gravity, and in the composite fiber according to the present invention, it is necessary that the two kinds of hardly soluble polymers having different melting points are unevenly distributed in at least one layer other than the innermost layer.

[0028] Here, the phrase "the hardly soluble polymers having different melting points are unevenly distributed" in the present invention means that, among straight lines that pass through the fiber center and equally divide the fiber cross section into two, there is a straight line (for example, a straight line I in (a) of FIG. 1) dividing the fiber cross section such that an area ratio of a hardly soluble polymer on a high melting point side and a hardly soluble polymer on a low melting point side in fiber cross sections on left and right sides or upper and lower sides is in a range of 100:0 to 70:30 in either fiber cross section and in a range of 30:70 to 0:100 in the other fiber cross section.

[0029] A composite structure in the composite fiber of the present invention is not particularly limited as long as the hardly soluble polymers having different melting points are unevenly distributed. Examples of the composite structure include a side-by-side type as shown in (a) and (c) of FIG. 1, a sea-island type as shown in (b) of FIG. 1, an eccentric core-sheath type as shown in (d) of FIG. 1, and a blend type. Among these composite structures, from the viewpoint of increasing a crimp development property by increasing the distance between the centers of gravity, it is preferable that the hardly soluble polymers having different melting points are bonded in a side-by-side type in which the hardly soluble polymers are completely separated.

[0030] When the hardly soluble polymers are bonded in the side-by-side type, since an interface between the hardly

soluble polymers having different melting points is small, the distance between the centers of gravity of the polymers in the composite cross section can be maximized, and the crimp development property can be maximized. Since the crimped form has a fine spiral structure, excellent stretchability can be imparted, and stress-free wearing comfort can be obtained using the fabric having appropriate stretchability, which is preferable.

[0031] In the fiber cross section of the composite fiber according to the present invention, a relationship between an inscribed circle diameter RA and a circumscribed circle diameter RB of the fiber is preferably $1.2 \leq RB/RA \leq 2.4$.

[0032] Here, the inscribed circle diameter RA and the circumscribed circle diameter RB in the present invention are obtained by embedding the fiber in an embedding agent such as an epoxy resin, and capturing an image of a fiber cross section perpendicular to a fiber axis with a scanning electron microscope (SEM) at a magnification at which the fibers of 10 filaments or more can be observed.

[0033] By analyzing, using image analysis software, the fibers randomly extracted in the same image selected from captured images, a diameter of a circle (for example, A in (a) of FIG. 2) that is inscribed at least two points (for example, a1 and a2 in (a) of FIG. 2) with the fiber surface, that is present only inside the fiber, and that has a maximum possible diameter within a range in which a circumference of an inscribed circle and the fiber surface do not intersect, is calculated, a simple number average of results obtained by performing the calculation for the ten filaments is obtained, and a value obtained by rounding off to the nearest whole number is set as the inscribed circle diameter RA.

[0034] A diameter of a circle (for example, B in (a) of FIG. 2) that circumscribes the fiber surface at least two points (for example, b1 and b2 in (a) of FIG. 2), that is present only outside the fiber, and that has a minimum possible diameter within a range in which a circumference of a circumscribed circle and the fiber surface do not intersect, is calculated, a simple number average of results obtained by performing the calculation for the ten filaments is obtained, and a value obtained by rounding off to the nearest whole number is set as the circumscribed circle diameter RB.

[0035] RB/RA is a value obtained by dividing RB by RA obtained in each fiber as described above, calculating a simple number average of results obtained by performing the calculation for the 10 filaments, and rounding off to the first decimal place.

[0036] In the composite fiber according to the present invention, a cross-sectional shape thereof is not limited, and it is important that the fibers are crimped and twisted after being subjected to the high-order processing such as weaving and knitting, so that the adjacent fibers and the crimped forms are intertwined with each other to develop the inter-fiber voids of various sizes. From this viewpoint, when the fiber cross section is a modified cross section, the inter-fiber voids generated when the fiber is twisted can be more complicated and increased, and thus RB/RA (modification degree), which is a ratio of the inscribed circle diameter RA and the circumscribed circle diameter RB of the fiber, is preferably 1.2 or more.

[0037] Furthermore, when RB/RA is 1.5 or more, the inter-fiber voids can be stably formed without crimp phases being aligned between the adjacent fibers, and the fabric can have a uniform appearance without unevenness such as a streak, and thus such a range is more preferable from the viewpoint of quality control. Larger RB/RA is preferable from the viewpoint of stably forming the inter-fiber voids, but in some cases, light reflected on the fiber surface is glaring, and the flexibility may be impaired since bending stiffness is increased more than necessary due to a cross-sectional shape including an edge, and thus a substantial upper limit value of RB/RA is 2.4.

[0038] When the cross-sectional shape of the composite fiber according to the present invention is the modified cross-sectional shape, any modified cross-sectional shape such as a flat shape, a multi-lobal shape, a polygonal shape, a gear shape, a petaloid shape, and a star shape can be adopted, but from the viewpoint of further enhancing the moderate resilience and the flexibility, a fiber shape is preferably a flat shape as shown in (a) of FIG. 2 or a multi-lobal shape as shown in (b) of FIG. 2. In a case in which the cross-sectional shape is the flat shape as shown in (a) of FIG. 2, when the fiber is bent along a plane perpendicular to a long axis of a flat cross section, the resilience due to high bending stiffness is obtained, and when the fiber is bent along a plane perpendicular to a short axis thereof, the flexibility due to low bending stiffness is obtained, and thus it is possible to obtain a texture that has the moderate resilience and softness.

[0039] In a case of a multifilament, when the crimped forms are developed and the fibers are twisted, the inter-fiber voids due to steric hindrance are increased, and the moderate resilience and a puffy feel can be further enhanced, and when long axis directions of the cross sections of the flat fibers are partially aligned, differences in voids and irregularities are generated between the adjacent fibers where the long axis directions of the cross sections thereof are aligned and where the long axis directions thereof are not aligned when the fibers are made into the textile, and thus the complicated voids and the irregularities can be formed between the fibers. Accordingly, also from the viewpoint that the specific tactile sensation peculiar to nature can be developed, the flat shape is preferable.

[0040] On the other hand, in a case in which the cross-sectional shape is the multi-lobal shape as shown in (b) of FIG. 2, irregularities are provided on the fiber surface, which is preferable from the viewpoint that glare due to diffuse reflection of the light is prevented and a water-absorbing quick-drying property due to the fine inter-fiber voids is improved. However, when the number of irregular portions is too large, an interval between the irregular portions becomes smaller, and an effect thereof gradually becomes smaller, and thus a substantial upper limit of convex portions of the multi-lobal shape in the present invention is 20.

[0041] Further, in a case in which the cross-sectional shape is a combination of the flat shape and the multi-lobal shape as shown in (c) of FIG. 2, the above-described features of the flat shape and the multi-lobal shape can be combined. Therefore, from the viewpoint of providing the moderate resilience and the puffy and soft texture as the textile as an object of the present invention and also having the function such as a water-absorbing quick-drying property, it is particularly preferable that the cross-sectional shape is the combination of the flat shape and the multi-lobal shape.

[0042] In the fiber cross section of the composite fiber according to the present invention, it is preferable that a communication portion is provided in which the easily soluble polymer communicates from the fiber center to the fiber surface.

[0043] In the composite fiber according to the present invention, it is necessary to elute the easily soluble polymer of the innermost layer in order to stably form the hollow portion inside the fiber. Further, since dissolution and removal of the easily soluble polymer by the solvent is performed from the fiber surface, when the communication portion from the fiber surface to the innermost layer can be provided, a time required for the dissolution of the easily soluble polymer can be remarkably shortened, and water absorbency and water retentivity due to the capillary phenomenon can be imparted to an opening portion formed after the elution of the easily soluble polymer. From this viewpoint, the easily soluble polymer preferably communicates from the fiber center to the fiber surface.

[0044] A communication width of the easily soluble polymer is preferably 10% or less of a fiber diameter.

[0045] Here, the fiber diameter in the present invention is obtained by embedding the composite fiber in the embedding agent such as an epoxy resin, and capturing an image of a fiber cross section perpendicular to a fiber axis with the scanning electron microscope (SEM) at a magnification at which the fibers of 10 filaments or more can be observed. Diameters of fibers randomly extracted in the same image selected from captured images are measured in units of μm to the first decimal place, a simple number average of results obtained by performing the measurement for the 10 filaments is obtained, and a value obtained by rounding off to the nearest whole number is defined as the fiber diameter (μm). Here, in a case in which the fiber cross section perpendicular to the fiber axis is not a perfect circle, an area thereof is measured, and a value of a diameter obtained by conversion to a perfect circle is adopted.

[0046] In order to obtain the communication width in the present invention, first, the composite fiber according to the present invention is embedded in the embedding agent such as an epoxy resin, and an image of the fiber cross section perpendicular to the fiber axis is captured with a transmission electron microscope (TEM) at a magnification at which 10 or more fibers can be observed. Further, in the composite fiber of the obtained image, when the easily soluble polymer communicates from the fiber center to the fiber surface, a shortest width of a width W (for example, W in (c) of FIG. 3) of the communication portion perpendicular to a straight line S (for example, S in (c) of FIG. 3) that passes through a fiber center G and is parallel to the communication portion is calculated in units of μm by performing analysis using the image analysis software. A simple number average of results obtained by performing the calculation for the 10 filaments is obtained, and a value obtained by rounding off to the first decimal place is defined as the communication width.

[0047] A value obtained by dividing a division width obtained for each filament by the fiber diameter and multiplying by 100 is calculated, a simple number average of results obtained by performing the calculation for 10 filaments is obtained, and a value obtained by rounding off to the nearest whole number is defined as a ratio (%) of the communication width to the fiber diameter.

[0048] When the communication width of the easily soluble polymer is 10% or less of the fiber diameter, it is possible to prevent the fibers from being caught in each other due to excessively wide opening portions formed after the removal of the easily soluble polymer, and to prevent the hollow portions from being crushed due to a deviation of the opening portions, and it is possible to prevent the moderate resilience and the puffy and soft texture from being impaired.

[0049] Furthermore, when the communication width is 5% or less of the fiber diameter, fibrillation due to fiber abrasion caused by the opening portion formed after the elution of the easily soluble polymer can be prevented, and in a case in which post-processing such as application of a functional agent is performed, the functional agent entering the hollow portion can be prevented from falling off due to washing or the like, and performance durability of the functional agent can be greatly improved, and thus such a range is more preferable. However, if the communication width is too narrow, since the dissolution of the easily soluble polymer is difficult, a substantial lower limit of the communication width is 1% of the fiber diameter.

[0050] In the fiber cross section of the composite fiber according to the present invention, it is preferable that the outermost layer includes an easily soluble polymer, and it is more preferable that the outermost layer is made of the easily soluble polymer. However, the outermost layer in the present invention refers to a layer containing 80% or more of the fiber surface.

[0051] When the outermost layer is made of the easily soluble polymer, the inter-fiber voids are naturally widened when the easily soluble polymer is removed, and an effect of improving the flexibility due to movable fibers fixed at binding points of a woven or knitted fabric and an effect of improving the lightweight feel due to a decrease in apparent density at high porosity can be obtained.

[0052] From this viewpoint, it is preferable that an area ratio of the outermost layer in the fiber cross section of the composite fiber is high, and when the area ratio thereof is 10% or more, the effect of improving the flexibility and the

lightweight feel can be sufficiently obtained without being influenced by a fabric structure, and thus such a range is more preferable. However, when the area ratio is too high, a reduction in resilience due to a reduction in bending stiffness may be caused, and thus a substantial upper limit thereof is 30%.

[0053] With the composite fiber according to the present invention, it is possible to obtain a hollow fiber containing only the hardly soluble polymers by once subjecting the composite fiber to the high-order processing such as weaving and knitting and heat-treating the composite fiber to develop the crimped form, and then removing the easily soluble polymer in the innermost layer, and to obtain a multifilament formed of the hollow fibers. From the multifilament, it is possible to obtain a textile excellent in wearing comfort, which has the functions such as a water-absorbing quick-drying property and stretchability, while having the moderate resilience and the puffy and soft texture, from the specific fiber cross-sectional shape and the inter-fiber voids.

[0054] Furthermore, in order to maximize the unique tactile sensation and texture due to the formation of the complicated voids and the irregularities unique to nature as the multifilament, the present inventors have conducted the extensive studies, and have found that the complicated voids and the irregularities, which have been difficult to obtain with the synthetic fiber of the background art or the textured yarn using the same, can be formed by controlling twisting of the flat fibers and appropriately aligning the long axis directions of the cross sections thereof.

[0055] That is, in the multifilament formed of the flat fibers that are not twisted, the voids obtained by aligning all the long axis directions of the cross sections of the fibers are small, and the irregularities are also small. On the other hand, in a case of the multifilament formed of the flat fibers to which the twisting has been applied by the false twisting process, since the twisting of each fiber is uniform and the long axis directions of the cross sections are oriented in different directions at the time of untwisting, the voids and the irregularities may be obtained but may be monotonous.

[0056] On the other hand, if the twisting is controlled such that the long axis directions of the cross sections of the flat fibers in the multifilament are partially aligned, the differences in the voids and the irregularities are generated between the adjacent fibers where the long axis directions of the cross sections are aligned and where the long axis directions thereof are not aligned when the multifilament is made into the textile, and thus the complicated voids and the irregularities can be formed between the fibers. Accordingly, the specific tactile sensation peculiar to nature can be developed, and in addition to the complicated voids and the irregularities between the fibers, by providing the hollow portion inside the fiber, the moderate resilience and the puffy and soft texture can be developed.

[0057] The present invention is constructed by designing the fibers based on this idea, and specifically, the multifilament according to the present invention includes flat hollow fibers. The multifilament according to the present invention is preferably made of the flat hollow fibers, and a variation coefficient CV of a rotation angle of a long axis of the flat hollow fiber in the multifilament is 15% to 50%.

[0058] In the present invention, it is important that the fiber constituting the textile is the flat hollow fiber.

[0059] When the fiber cross section is a flat cross section as shown in (a) of FIG. 5, when the fiber is bent along a plane perpendicular to the long axis of the flat cross section, the resilience due to the high bending stiffness is obtained, and when the fiber is bent along a plane perpendicular to a short axis thereof, the flexibility due to the low bending stiffness is obtained, and thus it is possible to obtain the texture that has the moderate resilience and the softness.

[0060] In order to exhibit the above effect, flatness is preferably 1.2 or more, and more preferably 1.5 or more. Within this range, the inter-fiber voids are formed by the steric hindrance when the flat hollow fibers are twisted, and the puffy feel in the textile is also obtained.

[0061] Higher flatness is preferable from the viewpoint of stably forming the inter-fiber voids, but in some cases, appearance unevenness (glare) is generated in the light reflected on the fiber surface, and the flexibility may be impaired since the bending stiffness is increased more than necessary due to a cross-sectional shape including the edge, and thus an upper limit of the flatness in the present invention is 2.4.

[0062] Here, the flatness in the present invention is obtained by embedding the multifilament in the embedding agent such as an epoxy resin, and capturing an image of a fiber cross section perpendicular to a fiber axis with the scanning electron microscope (SEM) at a magnification at which 10 or more fibers can be observed. By analyzing, using the image analysis software, fibers randomly extracted in the same image selected from captured images, a value obtained by dividing a length of the long axis by a length of the short axis is calculated, with a straight line (c1-c2) connecting two points (c1 and c2) farthest from each other among all the points on a fiber outer periphery as the long axis, and a straight line (d1-d2) passing through a midpoint of the long axis and orthogonal to the long axis as the short axis, as shown in (a) of FIG. 5. A simple number average of results obtained by performing the calculation for the 10 fibers is obtained, and a value obtained by rounding off to the first decimal place is defined as the flatness.

[0063] By providing the hollow portion inside the fiber, the puffy feel and the lightweight feel of the textile are improved, each fiber can be flexibly deformed while having the moderate resilience, and the effect of the flat cross section described above can be emphasized.

[0064] Furthermore, as the hollow ratio inside the fiber increases, the puffy feel and the lightweight feel are remarkably improved, and thus in the flat hollow fiber of the multifilament according to the present invention, an area ratio of the hollow portion including a fiber center is preferably 10% or more. In order to improve porosity of a fiber bundle to

emphasize the lightweight feel and emphasize the flexibility of the fabric, a more preferable range is that the area ratio of the hollow portion is 20% or more. In a case in which the area ratio is within such a range, when the fiber cross section is the flat cross section described above, the deformation of the single-fiber has directionality, and by exhibiting the twisted form, which is a feature of the present invention, the fiber bundle is intricately deformed, resulting in a very comfortable tactile sensation that cannot be experienced with yarn processing in the background art.

[0065] It is preferable from the viewpoint that the higher the area ratio of the hollow portion, the more remarkable the lightweight feel of the fiber bundle or the textile. However, when a thickness of the polymer constituting the fiber is reduced, strength is likely to be reduced or the hollow portion is likely to be crushed, and there is a possibility that a portion in which the comfortable resilience that is an object of the present invention cannot be well exhibited is present, and thus a substantial upper limit of the area ratio of the hollow portion in the present invention is 50%.

[0066] Here, the hollow ratio in the present invention is obtained by embedding the multifilament in the embedding agent such as an epoxy resin, and capturing an image of the fiber cross section perpendicular to the fiber axis with the scanning electron microscope (SEM) at the magnification at which 10 or more fibers can be observed. When each of fibers randomly extracted in the same image selected from captured images includes a hollow portion such as H in (a) of FIG. 5, for example, by performing analysis using the image analysis software, an area obtained from an outer shape including the hollow portion of the fiber and an area of the hollow portion are obtained, and a value obtained by dividing the area of the hollow portion by the area obtained from the outer shape including the hollow portion of the fiber and multiplying by 100 is calculated. A simple number average of results obtained by performing the calculation for the 10 fibers is obtained, and a value obtained by rounding off to the nearest whole number is defined as the hollow ratio (%).

[0067] In addition to the flat shape as shown in (a) of FIG. 5, it is preferable to combine cross-sectional shapes (multi-lobal shape, polygonal shape, gear shape, petaloid shape, star shape, or the like) including convex portions on the fiber surface as the cross-sectional shape. A reason therefor is that the combination can prevent appearance unevenness (glare) due to the diffuse reflection of the light and enhance the water absorbency due to the fine inter-fiber voids. However, if the number of convex portions is too large, the effect thereof gradually decreases, and thus a substantial upper limit of the convex portions is 20.

[0068] In the present invention, if the twisting is controlled such that the long axis directions of the cross sections of the flat fibers in the multifilament are partially aligned, the differences in the voids and the irregularities are generated between the adjacent fibers where the long axis directions of the cross sections are aligned and where the long axis directions thereof are not aligned when the multifilament is made into the textile. It is important that the variation coefficient CV of the rotation angle of the long axis of the flat hollow fiber in the multifilament is 15% to 50% as a requirement for forming the complicated voids generated between the fibers or the irregularities on a textile surface, which is a feature of the present invention.

[0069] The variation coefficient of the rotation angle of the long axis in the present invention is obtained by capturing an image of a fabric cross section perpendicular to a longitudinal direction of a fabric formed by the multifilament and perpendicular to a fiber axis direction of the multifilament with the scanning electron microscope (SEM) at a magnification at which 20 or more fibers can be observed. When fibers in the obtained image have flat cross sections, by performing analysis using the image analysis software, a straight line (c1-c2) connecting two points (c1 and c2) farthest from each other on a fiber outer periphery as shown in (b) FIG. 5 is defined as a long axis, a straight line passing through a midpoint of the long axis of the flat hollow fiber and parallel to a lower side of the captured image is rotated counterclockwise about the midpoint of the long axis, and a rotation angle (θ) when an inclination of the long axis and an inclination of the straight line coincide with each other is evaluated.

[0070] This evaluation is performed for 20 fibers ((1) to (20) in (b) of FIG. 5) randomly extracted from the multifilament in the same image, a standard deviation and an average value of evaluation results are obtained, a value obtained by dividing the standard deviation by the average value and multiplying by 100 is calculated, and a value obtained by rounding off to the nearest whole number is defined as the variation coefficient CV (%) of the rotation angle of the long axis.

[0071] In the present invention, the variation coefficient CV of the rotation angle of the long axis of the flat hollow fiber in the multifilament is required to be 15% or more, and by setting the variation coefficient CV in this range, the irregularities are generated on the textile surface due to misalignment in the long axis directions of the cross sections, and when a fabric surface is touched, friction fluctuation is large, and thus the soft tactile sensation is developed. Furthermore, due to the complicated voids formed between the fibers and the hollow portion inside the fiber, the moderate resilience and the puffy and soft texture are also developed.

[0072] The variation coefficient CV of the rotation angle of the long axis in the present invention is more preferably 25% to 40%, and when the variation coefficient CV is within this range, a pitch of the irregularities becomes fine, the soft tactile sensation is emphasized, apparent density is reduced when the fabric is formed by increasing the inter-fiber voids, and the effect of improving the puffy feel is improved. On the other hand, if the variation coefficient CV is too large, the irregularities are too fine and the friction fluctuation also is small, so that the tactile sensation becomes monotonous, and thus a substantial upper limit of the variation coefficient CV is 50%.

[0073] In order to control the variation coefficient of the rotation angle of the long axis of the flat hollow fiber in the

multifilament, a method is considered in which the flat hollow fibers having different twists are separately produced by the false twisting process or the like, and then the flat hollow fibers are blended and bundled by entanglement or the like. If a crimped form can be developed in the flat hollow fiber after the high-order processing such as weaving and knitting is performed using the flat hollow fiber having a latent crimping property which can be crimped by a heat treatment,

the variation coefficient CV of the rotation angle of the long axis in the flat hollow fiber in the multifilament can be easily set within a target range by locally generating a crimp phase difference between the fibers at the time of crimp-developing. **[0074]** From this viewpoint, in order to obtain a fiber having the latent crimping property which can be crimped by a heat treatment, in the flat hollow fiber of the multifilament according to the present invention, it is preferable that the fiber cross section is formed by at least two kinds of polymers having different melting points. When the fiber cross section is formed by polymers having different melting points, the fiber is largely curved toward a highly shrinkable polymer side after the heat treatment due to differential shrinkage caused by a melting point difference, and a three-dimensional spiral structure is formed when the curvature continues.

[0075] In order to enhance a crimp development property, it is preferable to form a composite cross section in which the polymers having the different melting points maintain a sufficient distance between the centers of gravity, and from this viewpoint, it is more preferable to bond the polymers having the different melting points in a side-by-side manner as shown in (a) of FIG. 6. That is, when an interface between the polymers having the different melting points is small, the distance between the centers of gravity of the polymers in the composite cross section can be maximized, and the crimp development property can be maximized.

[0076] Furthermore, since the crimped form has a fine spiral structure, excellent stretchability can also be imparted, and stress-free wearing comfort can be obtained using the fabric having appropriate stretchability.

[0077] Furthermore, it is particularly preferable that the flat hollow fibers in the multifilament have cross-sectional shapes (four types in FIG. 9 are examples of the cross-sectional shape) in which a direction (angle) of a bonding surface of the polymers having the different melting points is random for each single-fiber, and the crimp phase difference between the fibers can be increased since the crimped forms of single-fibers developed by the heat treatment are different due to a difference in distance between the centers of gravity. Due to this effect, the variation coefficient (CV) of the rotation angle of the long axis of the flat hollow fiber in the multifilament can be brought closer to an optimal range.

[0078] In the multifilament according to the present invention, the following composite fibers are preferably used in order to stably form the hollow portion of the flat hollow fiber without being affected by a structure which is woven, knitted, or the like while setting the variation coefficient of the rotation angle of the long axis of the flat hollow fiber in the multifilament to a target range. That is, it is preferable to use a composite fiber in which two or more kinds of polymers having different dissolution rates in a solvent are laminated in a direction from a fiber center to a fiber surface in the fiber cross section, an innermost layer including the fiber center includes an easily soluble polymer, and at least one layer other than the innermost layer includes two kinds of hardly soluble polymers having different melting points.

[0079] When the composite fiber is subjected to the high-order processing such as weaving and knitting, the crimped form is developed by the heat treatment, and then the easily soluble polymer in the innermost layer is removed, the multifilament formed of the flat hollow fibers stably formed without collapse of the hollow portions at the time of the high-order processing is obtained, and the variation coefficient of the rotation angle of the long axis in the flat hollow fiber in the multifilament can be set within the target range by developing the crimp.

[0080] When the flat hollow fiber in the multifilament according to the present invention develops the crimped form by the heat treatment, the flat hollow fiber preferably has a crimped form in which the number of crimped peaks is 5 peaks/cm or more.

[0081] Here, the number of crimped peaks in the present invention can be determined by the following method. That is, in the fabric made of the multifilament, the multifilament is extracted from the fabric so as not to be plastically deformed, and one end of the multifilament is fixed. After a load of 1 mg/dtex is applied to the other end and 30 seconds or more have elapsed, a marking is applied to an arbitrary portion where a distance between two points in the fiber axis direction of the multifilament is 1 cm.

[0082] Thereafter, the fiber is separated from the multifilament so as not to be plastically deformed, adjusted such that an interval between the previously attached markings is 1 cm, and fixed on slide glass. An image of this sample is captured at a magnification at which 1 cm marking can be observed with a digital microscope. When the multifilament has a crimped form in which the fiber is twisted as shown in FIG. 11 in the captured image, the number of crimped peaks present between the markings is obtained. A simple number average of results obtained by performing this operation on 10 fibers made of the same polymer is obtained, and a value obtained by rounding off to the nearest whole number is defined as the number of crimped peaks (peaks/cm).

[0083] When the fiber has a crimped form in which the number of crimped peaks is 5 peaks/cm or more, the variation coefficient CV of the rotation angle of the long axis of the flat hollow fiber in the multifilament can be set within a target range since the crimp phase difference between the fibers is locally generated at the time of crimp-developing.

[0084] Further, when the number of crimped peaks is 10 peaks/cm or more, an effect of improving the puffy feel caused by an increase in inter-fiber voids due to an excluded volume effect between the fibers can be obtained, the stretchability

can be imparted due to the fine spiral structure of the crimped form, and thus such a range is more preferable.

[0085] From the viewpoint of imparting the stretchability, it is preferable to increase the number of crimped peaks, but when the number of crimped peaks is excessive, the variation coefficient CV of the rotation angle of the long axis of the flat hollow fiber in the multifilament also increases, and a monotonous tactile sensation may be obtained depending on a structure of the woven or knitted fabric or the like. Accordingly, a substantial upper limit of the number of crimped peaks in the present invention for the purpose of developing a suitable tactile sensation is 50 peaks/cm.

[0086] The flat hollow fiber in the multifilament according to the present invention preferably includes an opening portion formed in a direction from the fiber center to the fiber surface. When the opening portion communicating with the hollow portion is provided, the water absorbency due to the capillary phenomenon at the opening portion is developed, and by increasing a fiber surface area, an effective area of the functional agent is increased when the post-processing such as application of the functional agent is performed, and the performance of the functional agent can be improved.

[0087] A width of the opening portion is preferably 10% or less of the fiber diameter. Here, the fiber diameter in the present invention is obtained by embedding the multifilament in the embedding agent such as an epoxy resin, and capturing an image of a fiber cross section perpendicular to a fiber axis with the scanning electron microscope (SEM) at a magnification at which the fibers of 10 filaments or more can be observed. Areas of fibers randomly extracted in the same image selected from captured images are measured, diameters obtained by conversion to a perfect circle are measured in units of μm to the first decimal place, a simple number average of results obtained by performing the measurement for the 10 filaments is obtained, and a value obtained by rounding off to the nearest whole number is defined as the fiber diameter (μm). Here, in a case in which a hollow portion is present in the fiber cross section perpendicular to the fiber axis, an area of the hollow portion is also added to an area of the fiber.

[0088] A width of the opening portion in the present invention can be determined by the following method. That is, the multifilament is embedded in the embedding agent such as an epoxy resin, and an image of a fiber cross section perpendicular to the fiber axis is captured with the transmission electron microscope (TEM) at a magnification at which 10 or more fibers can be observed. When the fiber in the obtained image includes an opening portion from a fiber center to a fiber surface, a shortest width among widths W' (for example, W' in (b) of FIG. 6) of the opening portion perpendicular to a straight line S' (for example, S' in (b) of FIG. 6) passing through the fiber center G and parallel to the opening portion is calculated in units of μm by performing analysis using the image analysis software. A simple number average of results obtained by performing the calculation for the 10 filaments is obtained, and a value obtained by rounding off to the first decimal place is defined as the width of the opening portion. A value obtained by dividing the width of the opening portion obtained for each filament by the fiber diameter and multiplying by 100 is calculated, a simple number average of results obtained by performing the calculation for the 10 filaments is obtained, and a value obtained by rounding off to the nearest whole number is defined as a ratio (%) of the width of the opening portion to the fiber diameter in the present invention.

[0089] In the present invention, the width of the opening portion is preferably 10% or less of the fiber diameter. That is, in such a range, it is possible to prevent the fibers from being caught in each other due to excessively wide opening portions, and to prevent the hollow portions from being crushed due to a deviation of the opening portions, and it is possible to prevent the texture such as a lightweight feel and moderate resilience from being impaired.

[0090] It is more preferable that the width of the opening portion is 5% or less of the fiber diameter, so that the fibrillation due to the fiber abrasion caused by the opening portion can be prevented, and in the case in which post-processing such as application of the functional agent is performed, the functional agent entering the hollow portion can be prevented from falling off due to the washing or the like, and the performance durability of the functional agent can be greatly improved. However, if the width of the opening portion is too narrow, when the water absorbency due to the capillary phenomenon at the opening portion may be weakened, or the functional agent may not sufficiently enter the hollow portion when the functional agent is applied, and thus a substantial lower limit of the width of the opening portion in the present invention is 1% of the fiber diameter.

[0091] Polymers constituting the composite fiber, the hollow fiber, and the flat hollow fiber in the multifilament according to the present invention is preferably thermoplastic polymers because of excellent processability. Preferable examples of the polymers constituting the fiber include polyester-based polymers, polyethylene-based polymers, polypropylene-based polymers, polystyrene-based polymers, polyamide-based polymers, polycarbonate-based polymers, polymethyl methacrylate-based polymers, and polyphenylene sulfide-based polymers and copolymers thereof.

[0092] From the viewpoint that particularly high interfacial affinity can be imparted and a fiber having no composite cross section abnormality can be obtained, it is preferable that all of the thermoplastic polymers used for the composite fiber, the hollow fiber, and the flat hollow fiber in the multifilament according to the present invention are the same polymers and copolymers thereof.

[0093] Inorganic substances such as titanium oxide, silica, and barium oxide, colorants such as carbon black, dyes, and pigments, and various additives such as flame retardants, fluorescent brighteners, antioxidants, and ultraviolet absorbers may also be contained in the polymer. In particular, the hardly soluble polymer preferably contains titanium oxide in an amount of 1.0% by mass or more. In this case, when the easily soluble polymer is dissolved, since titanium

oxide deposited on a surface of the hardly soluble polymers also falls off, irregularities are formed on the surface, and thus in addition to improving an appearance by preventing an increase or decrease in reflection (glare) depending on an incident angle of the light by diffusely reflecting the light, functionality such as anti-transparency and ultraviolet shielding due to titanium oxide inside the fiber is obtained.

[0094] The easily soluble polymer is preferably selected from polymers that can be melt-moldable polymers more soluble than other polymers, such as polyesters and copolymers thereof, polylactic acid, polyamides, polystyrene and copolymers thereof, polyethylene, and polyvinyl alcohol.

[0095] From the viewpoint of simplifying a step of eluting the easily soluble polymer, the easily soluble polymer is preferably a copolymerized polyester, polylactic acid, polyvinyl alcohol, or the like which exhibits an easily elutable property in an aqueous solvent, hot water, or the like. In particular, since the polymer exhibits the easily elutable property with respect to the aqueous solvent such as an aqueous alkaline solution while maintaining crystallinity, from the viewpoint of the high-order processing passing property that fusion or the like between the composite fibers does not occur even in the false twisting process or the like in which rubbing is applied under heating, a polyester in which 5 mol% to 15 mol% of 5-sodium sulfoisophthalic acid is copolymerized and a polyester in which 5 mass% to 15 mass% of polyethylene glycol having a weight average molecular weight of 500 to 3000 is copolymerized in addition to the above-described 5-sodium sulfoisophthalic acid are preferable.

[0096] The hardly soluble polymers having the different melting points in the present invention refer to a combination of polymers having a melting point difference of 10°C or more from melt-moldable thermoplastic polymers such as polyester-based polymers, polyethylene-based polymers, polypropylene-based polymers, polystyrene-based polymers, polyamide-based polymers, polycarbonate-based polymers, polymethyl methacrylate-based polymers, and polyphenylene sulfide-based polymers, and copolymers thereof.

[0097] In the composite fiber, the hollow fiber, and the flat hollow fiber in the multifilament according to the present invention, a purpose is to develop the crimped form due to the differential shrinkage of the hardly soluble polymers having the different melting points. Accordingly, as the combination of the hardly soluble polymers having the different melting points, it is preferable to use a low melting point polymer having high shrinkage as one of the polymers and a high melting point polymer having low shrinkage as the other one of the polymers. In particular, from the viewpoint of imparting stability of the high-order processing and use durability to the fabric by preventing peeling, the combination of the polymers is more preferably selected from the same polymer group in which bonds present in a main chain are the same, such as polyester-based polymers having ester bonds and polyamide-based polymers having amide bonds.

[0098] Examples of the combination of the low melting point polymer and the high melting point polymer in the same polymer group include various combinations such as copolymerized polyethylene terephthalate/polyethylene terephthalate, polybutylene terephthalate/polyethylene terephthalate, polytrimethylene terephthalate/polyethylene terephthalate, thermoplastic polyurethane/polyethylene terephthalate, polyester-based elastomers/polyethylene terephthalate, polyester-based elastomers/polybutylene terephthalate as polyester-based polymers; nylon 66/nylon 610, nylon 6-nylon 66 copolymers/nylon 6 or 610, PEG copolymerized nylon 6/nylon 6 or 610, thermoplastic polyurethane/nylon 6 or 610 as polyamide-based polymers; and ethylene-propylene rubber finely dispersed polypropylene/polypropylene, and propylene- α olefin copolymers/polypropylene as polyolefin-based polymers.

[0099] Among these, the hardly soluble polymers having the different melting points are preferably a combination of the polyester-based polymers from the viewpoint of preventing the collapse of the hollow portion inside the fiber due to the high bending stiffness and obtaining a good color development property when dyed.

[0100] Examples of a copolymerizing component in the copolymerized polyethylene terephthalate include succinic acid, adipic acid, azelaic acid, sebacic acid, 1,4-cyclohexane dicarboxylic acid, maleic acid, phthalic acid, isophthalic acid, and 5-sodium sulfoisophthalic acid, and from the viewpoint of maximizing the differential shrinkage from polyethylene terephthalate, it is preferable to use polyethylene terephthalate copolymerized with 5 mol% to 15 mol% of isophthalic acid.

[0101] While attention is focused on environmental problems, it is preferable to use plant-derived biopolymers and recycled polymers in the present invention from the viewpoint of reducing an environmental load. As such polymers used in the present invention, recycled polymers recycled by any of chemical recycling, material recycling and thermal recycling can be used.

[0102] Even in a case of using the biopolymers or the recycled polymers, the feature of the present invention can be made remarkable in a polyester-based resin as polymer characteristics thereof, and as described above, the collapse of the hollow portion inside the fiber can be prevented due to the high bending stiffness, and the good color development property can be obtained when dyed. From these viewpoints, the recycled polyesters can be suitably used in the present invention.

[0103] An area ratio of the hardly soluble polymer on the low melting point side to the hardly soluble polymer as the high melting point polymer in the composite fiber, the hollow fiber, and the flat hollow fibers of the multifilament according to the present invention is preferably in a range of 70/30 to 30/70 in terms of the low melting point/high melting point. When the ratio is within this range, the low melting point polymer can sufficiently develop the crimped form due to the differential shrinkage without being affected by texture curing due to clogging when the low melting point polymer is

highly shrunk by the heat treatment, and more coarsened inter-fiber voids can be obtained.

[0104] In the composite fiber, the hollow fiber, and the flat hollow fiber in the multifilament according to the present invention, a fiber diameter is preferably 20 μm or less from the viewpoint of making the texture more flexible. When the fiber diameter is within this range, in addition to the flexibility, the resilience can be sufficiently obtained, and this range is suitable for clothing applications such as pants and shirts in which a texture with moderate stiffness and tension is required.

[0105] Further, it is more preferable to set the fiber diameter to 15 μm or less, and by setting in this manner, the fiber bundle or the fabric made of the fiber bundle is more flexible, and is suitably used for clothing applications such as inner wear or blouses in contact with a skin. However, when the fiber diameter is less than 8 μm , since the fiber diameter is too small, a portion in which bending recovery is deteriorated may be generated, or the color development property may be deteriorated. Accordingly, the fiber diameter of the fiber in the present invention is preferably 8 μm or more.

[0106] In a fiber product according to the present invention at least partially including the composite fiber, the hollow fiber, and the multifilament according to the present invention, when the fiber product is formed, differences are generated in the voids or the irregularities between the adjacent fibers where the long axis directions of the cross sections are aligned and where the long axis directions thereof are not aligned, the complicated voids or the irregularities can be formed between the fibers, and a specific and soft tactile sensation can be developed. Further, since the hollow portion is provided inside the fiber, the textile excellent in the wearing comfort can be obtained in which the moderate resilience and the puffy and soft texture are achieved due to the complicated voids and the irregularities between the fibers.

[0107] Accordingly, the composite fiber, the hollow fiber, and the multifilament according to the present invention can be suitably used for a wide variety of fiber products, from general clothing such as jackets, skirts, pants, and underwear, to interior products such as carpets and sofas, vehicle interior products such as car seats, home applications such as cosmetics, cosmetic masks, and health products in addition to sports clothing and clothing materials, taking advantage of comfortability thereof.

[0108] An example of a method for producing the composite fiber, the hollow fiber, and the multifilament according to the present invention will be described in detail below.

[0109] Examples of the method for producing the composite fiber, the hollow fiber, and the multifilament according to the present invention include a melt spinning method for a purpose of producing a long fiber, a wet or dry-wet solution spinning method, a melt blowing method and a spunbond method suitable for obtaining a sheet-shaped fiber structure, and the melt spinning method is preferable from the viewpoint of enhancing productivity.

[0110] In the melt spinning method, the fiber can be produced by using a composite spinneret to be described later, and a spinning temperature at this time is preferably set to a temperature at which mainly a high melting point polymer or a high viscosity polymer among the types of polymers to be used exhibits fluidity. Although the temperature at which the fluidity is exhibited varies depending on a molecular weight, it is possible to stably produce the fiber by setting the temperature between the melting point of the polymer and the melting point + 60°C.

[0111] A spinning speed may be about 500 m/min to 6,000 m/min, and can be changed depending on physical properties of the polymer and an intended use of the fiber. In particular, from the viewpoint of highly orienting the fiber for improving mechanical properties, it is preferable to set the spinning speed to 500 m/min to 4,000 m/min and then stretch the fiber, whereby uniaxial orientation of the fiber can be promoted. In the stretching, it is preferable to appropriately set a preheating temperature with reference to a softening temperature such as a glass transition temperature of the polymer. An upper limit of the preheating temperature is preferably set to a temperature at which a yarn path is not disturbed due to spontaneous elongation of the fiber in a preheating process. For example, in a case of PET (polyethylene terephthalate) having the glass transition temperature in the vicinity of 70°C, the preheating temperature is usually set to about 80°C to 95°C.

[0112] In addition, the composite fiber, the hollow fiber, and the multifilament according to the present invention can be stably produced by setting a discharge amount per hole in a spinneret to about 0.1 g/min/hole to 10 g/min/hole. After discharged polymer flows are cooled and solidified, an oil agent is applied to the polymer flows, and the polymer flows are taken up by a roller having a specified peripheral speed. Thereafter, the polymer flows are stretched by a heating roller to form a desired composite fiber, hollow fiber, and multifilament.

[0113] In the composite fiber according to the present invention including two or more kinds of polymers, by setting a melt viscosity ratio of the polymers to be used to less than 5.0 and setting a difference in solubility parameter value to less than 2.0, a composite polymer flow can be stably formed, and a fiber having a good composite cross section can be obtained, which is preferable.

[0114] As the composite spinneret used for producing the composite fiber according to the present invention including the two or more kinds of polymers, for example, a composite spinneret described in JP2011-208313A is preferably used.

[0115] The composite spinneret shown in FIG. 12 of the present invention is incorporated into a spin pack in a state in which roughly three types of members, that is, a measuring plate 1, a distribution plate 2 and a discharge plate 3 are laminated from above. Incidentally, FIG. 12 is an example using three types of polymers, a polymer A, a polymer B, and a polymer C. In the composite spinneret in the background art, it is difficult to composite three or more kinds of polymers,

and it is also preferable to use a composite spinneret using a fine flow path as illustrated in FIG. 12.

[0116] In the spinneret member illustrated in FIG. 12, an amount of polymer per discharge hole and an amount of polymer per distribution hole are measured by the measuring plate 1. The measured polymer flow is disposed by the distribution plate 2 such that a composite cross section of a single-fiber is formed, and the composite polymer flow

formed by the distribution plate 2 is compressed and discharged by the discharge plate 3.

[0117] Although not illustrated in order to avoid complication of the description of the composite spinneret, a member in which a flow path is formed may be used for a member to be laminated above the measuring plate 1, in accordance with a spinning machine and the spin pack. By designing the measuring plate 1 in accordance with an existing flow path member, an existing spin pack and a member thereof can be utilized as they are.

[0118] Therefore, a special spinning machine only adapted for use with the spinneret is not necessary. Actually, a plurality of flow path plates may be stacked between a flow path and a measuring plate or between the measuring plate 1 and the distribution plate 2. This is for a purpose of providing a flow path through which the polymer is effectively transferred in a cross-sectional direction of the spinneret and a cross-sectional direction of the single-fiber, and introducing the polymer into the distribution plate 2. After the composite polymer flow discharged from the discharge plate 3 is cooled and solidified in accordance with the above-described producing method, the oil agent is applied to the composite polymer flow, and the composite polymer flow is taken up by the roller having the specified peripheral speed. Thereafter, stretching processing is performed with the heating roller to obtain a desired composite fiber.

[0119] In order to obtain the hollow fiber made only of the hardly soluble polymers by eluting the easily soluble polymer of the innermost layer from the composite fiber according to the present invention, the composite fiber may be immersed in a solvent or the like capable of dissolving the easily soluble polymer to remove the easily soluble polymer. When the easily soluble polymer is copolymerized polyethylene terephthalate in which 5-sodium sulfoisophthalic acid, polyethylene glycol, or the like is copolymerized, polylactic acid, or the like, an aqueous alkaline solution such as a sodium hydroxide aqueous solution can be used.

[0120] As a method for treating the composite fiber according to the present invention with the aqueous alkaline solution, for example, a fiber structure formed by the composite fiber may be immersed in the aqueous alkaline solution. At this time, when the aqueous alkaline solution is heated to 50°C or higher, the progress of hydrolysis can be accelerated, which is preferable. When a fluid dyeing machine or the like is used, a large amount can be treated at a time, which is preferable from an industrial viewpoint.

[EXAMPLES]

[0121] Hereinafter, the composite fiber and the hollow fiber according to the present invention will be described in detail with reference to Examples.

[0122] Examples and Comparative Examples were evaluated as follows.

A. Melt Viscosity of Polymer

[0123] A chip-shaped polymer was dried to a moisture content of 200 ppm or less by a vacuum dryer, and a melt viscosity was measured by changing a strain rate stepwise by a capillograph manufactured by Toyo Seiki Seisaku-sho Co., Ltd. A measurement temperature was set in the same manner as the spinning temperature, and the measurement was started after a sample was put into a heating furnace under a nitrogen atmosphere for 5 minutes, and a value of a shear rate of 1216s⁻¹ was evaluated as the melt viscosity of the polymer.

B. Melting Point of Polymer

[0124] The chip-shaped polymer was dried to the moisture content of 200 ppm or less by the vacuum dryer, about 5 mg of the chip-shaped polymer was weighed, a temperature was increased from 0°C to 300°C at a temperature increase rate of 16°C/min and then held at 300°C for 5 minutes for DSC measurement using a differential scanning calorimeter (DSC), Q2000, manufactured by TA Instruments. A melting point was calculated from a melting peak observed during a heating process. The measurement was performed three times for each sample, and an average value thereof was taken as the melting point. When a plurality of melting peaks were observed, a top of the melting peak on a highest temperature side was defined as the melting point.

C. Fineness

[0125] A weight of 100 m of the fiber was measured, and a value obtained by multiplying the measured value by 100 was calculated. This operation was repeated 10 times, and a value obtained by rounding off an average value thereof to the first decimal place was defined as fineness (dtex).

D. Cross-sectional Parameter (RB/RA) of Composite Fiber

[0126] The diameter was obtained by embedding the composite fiber in the embedding agent such as an epoxy resin, and capturing an image of a fiber cross section perpendicular to a fiber axis with a scanning electron microscope (SEM) manufactured by Hitachi, Ltd. at the magnification at which the fibers of 10 filaments or more can be observed. By analyzing fibers randomly extracted in the same image selected from captured images using WinROOF manufactured by Mitani Corporation of computer software, the diameter of the circle (for example, A in (a) of FIG. 2) that is inscribed at least two points (for example, a1 and a2 in (a) of FIG. 2) with the fiber surface, that is present only inside the fiber, and that has the maximum possible diameter within the range in which the circumference of the inscribed circle and the fiber surface do not intersect, was calculated. The simple number average of the results obtained by performing the calculation for the 10 filaments was obtained, and the value obtained by rounding off to the nearest whole number was set as the inscribed circle diameter RA.

[0127] The diameter of the circle (for example, B in (a) of FIG. 2) that circumscribes the fiber surface at least two points (for example, b1 and b2 in (a) of FIG. 2), that is present only outside the fiber, and that has the minimum possible diameter within the range in which the circumference of the circumscribed circle and the fiber surface do not intersect, was calculated. A simple number average of the results obtained by performing the calculation for the ten filaments was obtained, and the value obtained by rounding off to the nearest whole number was set as the circumscribed circle diameter RB. The value obtained by dividing RB obtained for each fiber by RA was calculated, the simple number average of the results obtained by performing the calculation for the 10 filaments was obtained, and the value obtained by rounding off to the first decimal place was defined as RB/RA.

E. Fiber Diameter

[0128] The fiber diameter was obtained by embedding the composite fiber and the multifilament in the embedding agent such as an epoxy resin, and capturing the image of the fiber cross section perpendicular to the fiber axis with the scanning electron microscope (SEM) at the magnification at which the fibers of 10 filaments or more can be observed. The areas of the fibers randomly extracted in the same image selected from the captured images were measured, and the diameters obtained by conversion to the perfect circle were measured in units of μm to the first decimal place. The simple number average of the results obtained by performing the measurement for the 10 filaments was obtained, and the value obtained by rounding off to the nearest whole number was defined as the fiber diameter (μm). Here, in the case in which the hollow portion is present in the fiber cross section perpendicular to the fiber axis, the area of the hollow portion is also added to the area of the fiber.

F. Communication Width

[0129] The composite fiber was embedded in the embedding agent such as an epoxy resin, and the image of the fiber cross section perpendicular to the fiber axis was captured with the transmission electron microscope (TEM) at the magnification at which 10 or more fibers can be observed. In the composite fiber of the obtained image, when the easily soluble polymer communicates from the fiber center to the fiber surface, the shortest width of the width W (for example, W in (c) of FIG. 3) of the communication portion perpendicular to the straight line S (for example, S in (c) of FIG. 3) that passes through the fiber center G and is parallel to the communication portion was calculated in units of μm by performing analysis using WinROOF manufactured by Mitani Corporation of computer software. The simple number average of the results obtained by performing the calculation for the 10 filaments was obtained, and the value obtained by rounding off to the first decimal place is defined as the communication width. The value obtained by dividing the division width obtained for each filament by the fiber diameter and multiplying by 100 was calculated, the simple number average of the results obtained by performing the calculation for the 10 filaments was obtained, and the value obtained by rounding off to the nearest whole number was defined as the ratio (%) of the communication width to the fiber diameter.

G. Flatness

[0130] The flatness was obtained by embedding the multifilament in the embedding agent such as an epoxy resin, and capturing the image of the fiber cross section perpendicular to the fiber axis with the scanning electron microscope (SEM) manufactured by Hitachi, Ltd. at the magnification at which the ten or more fibers can be observed. By analyzing, using the image analysis software, the fibers randomly extracted in the same image selected from the captured images, the value obtained by dividing the length of the long axis by the length of the short axis was calculated, with the straight line (c1 - c2) connecting two points (c1 and c2) farthest from each other among all the points on the fiber outer periphery as the long axis, and the straight line (d1-d2) passing through the midpoint of the long axis and orthogonal to the long axis as the short axis, as shown in (a) of FIG. 5. The simple number average of the results obtained by performing the

calculation for the 10 fibers was obtained, and the value obtained by rounding off to the first decimal place was defined as the flatness.

H. Hollow Ratio

[0131] The hollow ratio was obtained by embedding the multifilament in the embedding agent such as an epoxy resin, and capturing the image of the fiber cross section perpendicular to the fiber axis with the scanning electron microscope (SEM) manufactured by Hitachi, Ltd. at the magnification at which the ten or more fibers can be observed. When each of the fibers randomly extracted in the same image selected from the captured images includes the hollow portion, by performing analysis using the image analysis software, the area obtained from the outer shape including the hollow portion of the fiber and the area of the hollow portion were obtained, and the value obtained by dividing the area of the hollow portion by the area obtained from the outer shape including the hollow portion of the fiber and multiplying by 100 was calculated. The simple number average of the results obtained by performing the calculation for the 10 fibers was obtained, and the value obtained by rounding off to the nearest whole number was defined as the hollow ratio (%).

I. Width of Opening Portion

[0132] The multifilament was embedded in the embedding agent such as an epoxy resin, and the image of the fiber cross section perpendicular to the fiber axis was captured with the transmission electron microscope (TEM) at the magnification at which 10 or more fibers can be observed. When the fiber in the obtained image includes the opening portion from the fiber center to the fiber surface, the shortest width among widths W' (for example, W' in (b) of FIG. 6) of the opening portion perpendicular to the straight line S' (for example, S' in (b) of FIG. 6) passing through the fiber center G and parallel to the opening portion was calculated in units of μm by performing the analysis using the image analysis software. The simple number average of the results obtained by performing the calculation for the 10 filaments was obtained, and the value obtained by rounding off to the first decimal place was defined as the width of the opening portion. The value obtained by dividing the width of the opening portion obtained for each filament by the fiber diameter and multiplying by 100 was calculated, the simple number average of the results obtained by performing the calculation for the 10 filaments was obtained, and the value obtained by rounding off to the nearest whole number was defined as the ratio (ratio of the opening portion) (%) of the width of the opening portion to the fiber diameter.

J. Number of Crimped Peaks (Peaks/cm)

[0133] In the fabric made of the multifilament, the multifilament was extracted from the fabric so as not to be plastically deformed, one end of the multifilament was fixed, and after the load of 1 mg/dtex was applied to the other end thereof and 30 seconds or more have elapsed, the marking was applied to an arbitrary portion where a distance between two points in the fiber axis direction of the multifilament was 1 cm. Thereafter, the fiber was separated from the multifilament so as not to be plastically deformed, and adjusted such that an interval between the previously attached markings was 1 cm, and fixed on the slide glass, and the image of this sample was captured at the magnification at which 1 cm marking can be observed with the digital microscope. When the multifilament has the crimped form in which the fiber was twisted as shown in FIG. 11 in the captured image, the number of crimped peaks present between the markings was obtained. The simple number average of the results obtained by performing this operation on the 10 fibers made of the same polymer was obtained, and the value obtained by rounding off to the nearest whole number was defined as the number of crimped peaks (peaks/cm).

K. Variation Coefficient CV of Rotation Angle of Long Axis

[0134] For the fabric formed by the multifilament, the image of the fabric cross section perpendicular to the longitudinal direction of the fabric and perpendicular to the fiber axis direction of the multifilament, was captured with the scanning electron microscope (SEM) manufactured by Hitachi, Ltd. at the magnification at which 20 or more fibers can be observed. When the fibers in the obtained image have the flat cross sections, by performing analysis using the image analysis software, the straight line (c1-c2) connecting two points (c1 and c2) farthest from each other on the fiber outer periphery as shown in (b) FIG. 5 was defined as the long axis, the straight line passing through the midpoint of the long axis of the flat hollow fiber and parallel to the lower side of the captured image was rotated counterclockwise about the midpoint of the long axis, and the rotation angle (θ) when the inclination of the long axis and the inclination of the straight line coincide with each other was evaluated. This evaluation was performed for the 20 fibers randomly extracted from the multifilament, the standard deviation and the average value of the evaluation results were obtained. The value obtained by dividing the standard deviation by the average value and multiplying by 100 was calculated, and the value obtained by rounding off to the nearest whole number was defined as the variation coefficient CV (%) of the rotation angle of the

long axis.

L. Texture Evaluation (Lightweight Feel, Flexibility, Resilience, Smoothness, Roughness)

[0135] The number of fibers was adjusted such that a cover factor (CFA) in a warp direction was 800 and a cover factor (CFB) in a weft direction was 1200, thereby producing a 3/1 twill woven textile. However, CFA and CFB herein were values obtained by measuring warp density and weft density of the woven fabric in a section of 2.54 cm in accordance with JIS-L-1096:2010 8.6.1 and calculating $CFA = \text{warp density} \times (\text{fineness of warp})^{1/2}$ and $CFB = \text{weft density} \times (\text{fineness of weft})^{1/2}$. The obtained woven fabric was subjected to scouring, a wet heat treatment, an alkali treatment, and heat setting, and then five textures, that is, the lightweight feel, flexibility, resilience, smoothness, and roughness were evaluated by the following methods.

[0136] The lightweight feel was evaluated by the following method. That is, a thickness (cm) of the woven fabric of 20 cm $\times$ 20 cm was measured under a constant pressure (0.7 kPa) using a constant-pressure thickness-measuring instrument (PG-14J) manufactured by Teloteck Co., Ltd. to calculate a volume of the woven fabric, and then a value obtained by dividing a weight (g) of the woven fabric by the obtained volume was defined as an apparent density (g/cm³) of the woven fabric. From the obtained apparent density, lightness was determined in three stages based on the following criteria.

A: Excellent lightweight feel (apparent density ≤ 0.34)

B: Good lightweight feel ($0.34 < \text{apparent density} \leq 0.44$)

C: Poor lightweight feel ($0.44 < \text{apparent density}$)

[0137] The flexibility was evaluated by the following method using a pure bending tester (KES-FB2) manufactured by Kato Tech Co., Ltd. That is, the woven fabric of 20 cm $\times$ 20 cm was held with an effective sample length of 20 cm $\times$ 1 cm, and bent in the weft direction under a condition of a maximum curvature $\pm 2.5 \text{ cm}^{-1}$. An average value of a value obtained by dividing, by a difference in curvature of 1 cm^{-1} , a difference in bending moment per unit width (gf-cm/cm) between curvatures of 0.5 cm^{-1} and 1.5 cm^{-1} and a value obtained by dividing, by a difference in curvature of 1 cm^{-1} , a difference in bending moment per unit width (gf-cm/cm) between curvatures of -0.5 cm^{-1} and -1.5 cm^{-1} was calculated. This operation was performed three times for each portion, and a simple number average of results obtained by performing this operation on a total of 10 portions was obtained, and a value obtained by rounding off to the third decimal place and then dividing a result of rounding-off by 100 was defined as bending hardness $B \times 10^{-2}$ (gf-cm²/cm). The flexibility was determined in three stages from the obtained bending hardness $B \times 10^{-2}$ on the basis of the following criteria.

A: Excellent flexibility (bending hardness $B \times 10^{-2} \leq 1.0$)

B: Good flexibility ($1.0 < \text{bending hardness } B \times 10^{-2} \leq 2.0$)

C: Poor flexibility ($2.0 < \text{bending hardness } B \times 10^{-2}$)

[0138] The resilience was evaluated by the following method. That is, using a pure bending tester (KES-FB2) manufactured by Kato Tech Co., Ltd., a woven fabric of 20 cm $\times$ 20 cm was held with an effective sample length of 20 cm $\times$ 1 cm, and a width (gf-cm/cm) of hysteresis at a curvature of $\pm 1.0 \text{ cm}^{-1}$ when the woven fabric was bent in the weft direction was calculated. This operation was performed three times for each portion, and a simple number average of results obtained by performing this operation on a total of 10 portions was obtained, and a value obtained by rounding off to the third decimal place and then dividing a result of rounding-off by 100 was defined as bending recovery $2HB \times 10^{-2}$ (gf-cm/cm). From the obtained bending recovery $2HB \times 10^{-2}$, the resilience was determined in three stages based on the following criteria.

A: Excellent resilience (bending recovery $2HB \times 10^{-2} \leq 1.0$)

B: Good resilience ($1.0 < \text{bending recovery } 2HB \times 10^{-2} \leq 2.0$)

C: Poor resilience ($2.0 < \text{bending recovery } 2HB \times 10^{-2}$)

[0139] Smoothness and the roughness were evaluated by the following methods. That is, using an automated surface tester (KES-FB4) manufactured by Kato Tech Co., Ltd., a load of 50 g was applied to a terminal of 1 cm $\times$ 1 cm, which was wrapped with a piano wire over a 10 cm $\times$ 10 cm area of the woven fabric of 20 cm $\times$ 20 cm, and the woven fabric was slid at a speed of 1.0 mm/sec to obtain an average friction coefficient MIU and a variation MMD of the average friction coefficient. This operation was performed three times for each portion, and the operation was performed for a total of 10 portions. As for results, a simple number average was obtained for the average friction coefficient MIU, and a value obtained by rounding off to the first decimal place was used as a friction coefficient. Based on the obtained friction coefficient, the smoothness was evaluated in three stages based on the following criteria.

- A: Excellent smoothness (friction coefficient < 0.5)
- B: Good smoothness ($0.5 \leq$ friction coefficient < 1.0)
- C: Poor smoothness ($1.0 \leq$ friction coefficient)

5 **[0140]** For the variation MMD of the average friction coefficient, a simple number average was obtained, and a value obtained by rounding off to the third decimal place was used as the friction fluctuation. From the obtained friction fluctuation, the roughness was evaluated in three stages based on the following criteria.

- 10 A: Excellent roughness ($0.9 \leq$ friction fluctuation)
- B: Good roughness ($0.5 \leq$ friction coefficient < 0.9)
- C: Poor roughness (friction coefficient < 0.5)

M. Function Evaluation (Water-absorbing Quick-drying Property, Stretchability)

15 **[0141]** The number of fibers was adjusted such that the cover factor (CFA) in the warp direction was 800 and the cover factor (CFB) in the weft direction was 1200, thereby producing the 3/1 twill woven textile. However, CFA and CFB herein were the values obtained by measuring the warp density and the weft density of the woven fabric in the section of 2.54 cm in accordance with JIS-L-1096:2010 8.6.1 and calculating $CFA = \text{warp density} \times (\text{fineness of warp})^{1/2}$ and $CFB = \text{weft density} \times (\text{fineness of weft})^{1/2}$. The obtained woven fabric was subjected to the scouring, the wet heat treatment, the alkali treatment, and the heat setting, and then two functions, that is, the water-absorbing quick-drying property and the stretchability were evaluated by the following methods.

20 **[0142]** The water-absorbing quick-drying property was evaluated by the following method. That is, 0.1 cc of water was added dropwise to a woven fabric of 10 cm $\times$ 10 cm, a weight of the woven fabric was measured every 5 minutes in an environment of a temperature of 20°C and relative humidity of 65 RH%, and a time (minutes) at which a residual moisture content was 1.0% or less was determined. A simple number average of results obtained by performing this operation on a total of three portions was obtained, and a value obtained by rounding off to the nearest whole number was defined as a water diffusion time (minutes). From the obtained water diffusion time, the water-absorbing quick-drying property was determined in three stages based on the following criteria.

- 30 A: Excellent water-absorbing quick-drying property (water diffusion time ≤ 20)
- B: Good water-absorbing quick-drying property ($20 < \text{water diffusion time} \leq 40$)
- C: Poor water-absorbing quick-drying property ($40 < \text{water diffusion time}$)

35 **[0143]** The stretchability was evaluated by the following method. That is, the stretchability was evaluated in accordance with elongation A method (constant rate elongation method) described in JIS L 1096:2010, Section 8.16.1. A load of 17.6 N (1.8 kg) in a strip method was adopted, and test conditions were a sample width of 5 cm $\times$ length of 20 cm, a clamping distance of 10 cm, and a tensile speed of 20 cm/min. As an initial load, a weight corresponding to a sample width of 1m was used in accordance with a method of JIS L1096:2010. A simple number average of results obtained by performing the test three times in a weft direction of the woven fabric was obtained, and a value obtained by rounding off to the nearest whole number was defined as fabric elongation (%). From the obtained fabric elongation, the stretchability was evaluated in three stages based on the following criteria.

- 40 A: Excellent stretchability ($15 \leq$ elongation)
- B: Good stretchability ($5 \leq$ elongation < 15)
- 45 C: Poor stretchability (elongation < 5)

N. Wear Resistance

50 **[0144]** The number of fibers was adjusted such that the cover factor (CFA) in the warp direction was 1100 and the cover factor (CFB) in the weft direction was 1100, thereby producing a plain weave fabric. The produced woven fabric was dyed in black with a disperse dye Sumikaron Black S-3B (10% owf). The dyed woven fabric was cut into a circle having a diameter of 10 cm, and the circle was wet with distilled water and attached to a disk. Further, the woven fabric cut into a 30 cm square was fixed on a horizontal plate in a dry state.

55 **[0145]** The disk to which the woven fabric wet with the distilled water was attached was brought into horizontal contact with the woven fabric fixed on the horizontal plate, and the disk was circularly moved at a load of 420 g and a speed of 50 rpm for 10 minutes such that a center of the disk drew a circle having a diameter of 10 cm, thereby rubbing the two woven fabrics. After leaving the fabrics for 4 hours after completion of the rubbing, a degree of color deterioration of the woven fabric attached to the disk was evaluated by grades 1 to 5 in increments of grade 0.5 using a gray scale for color

deterioration. The wear resistance was evaluated in three stages based on the following criteria from results of the obtained grade evaluation.

- A: Excellent wear resistance (grade evaluation: grade 4 or higher)
- B: Good wear resistance (grade evaluation: grade 3 or grade 3.5)
- C: Poor wear resistance (grade evaluation: less than grade 3).

[Example 1]

[0146] As a polymer 1, polyethylene terephthalate (SSIA-PEG copolymer PET, melt viscosity: 100 Pa·s, melting point: 233°C) obtained by copolymerizing 8 mol% of 5-sodium sulfoisophthalic acid and 9 mass% of polyethylene glycol was prepared.

[0147] As a polymer 2, polyethylene terephthalate (IPA-copolymerized PET, melt viscosity: 140 Pa·s, melting point: 232°C) copolymerized with 7 mol% of isophthalic acid was prepared.

[0148] As a polymer 3, polyethylene terephthalate (PET, melt viscosity: 130 Pa·s, melting point: 254°C) was prepared.

[0149] These polymers were separately melted at 290°C, and then the polymer 1/polymer 2/polymer 3 were weighed such that a weight ratio of the polymer 1/polymer 2/polymer 3 was 20/40/40 and flowed into the spin pack in which the composite spinneret shown in FIG. 5 was incorporated. Inflowing polymers were discharged from the discharge holes so as to form the flat composite fiber as shown in (a) of FIG. 3, which has a composite structure in which the polymer 1 was disposed in the innermost layer and the communication portion extending from the fiber center to the fiber surface, and the polymer 2 and the polymer 3 were joined to the outermost layer in the side-by-side manner.

[0150] After cooling and solidifying, the oil agent was applied to the discharged composite polymer flow, and the composite polymer flow was wound at a spinning speed of 1,500 m/min, and stretched between rollers heated to 90°C and 130°C to produce a composite fiber having 56 dtex-36 filaments (fiber diameter: 12 μm).

[0151] The ratio RB/RA of the inscribed circle diameter RA to the circumscribed circle diameter RB of the obtained composite fiber was 1.8. The communication width was 0.5 μm, which was a ratio of 4% with respect to the fiber diameter of 12 μm, and it was confirmed that the composite fiber according to the present invention was obtained.

[0152] The obtained composite fiber was woven, subjected to a scouring treatment at 80°C and a wet heat treatment at 130°C, and then treated in a 1% by mass of sodium hydroxide aqueous solution (bath ratio: 1:50) heated to 90°C to remove 99% or more of the polymer 1 as the easily soluble polymer. At this time, due to the presence of the communication portion from the fiber center to the fiber surface, the polymer 1 of the innermost layer was quickly eluted within 10 minutes after an elution treatment was started.

[0153] Thereafter, heat setting was applied at 180°C to obtain a woven fabric formed by a multifilament including flat hollow fibers having flatness of 1.8, a hollow ratio of 18%, and the number of crimped peaks of 17 peaks/cm as shown in (b) of FIG. 2. The flat hollow fiber had the opening portion, and the width of the opening portion was 0.5 μm, which was 4% of the fiber diameter.

[0154] In the woven fabric formed by the multifilament, the variation coefficient CV of the rotation angle of the long axis in the flat hollow fiber in the multifilament was 27%. Accordingly, since the long axis directions of the cross sections were misaligned, and thus the irregularities were developed on the textile surface. Accordingly, when the fabric surface was touched, it was possible to feel the soft tactile sensation due to the large roughness (friction fluctuation: 0.9×10^{-2}) while the surface was smooth (friction coefficient: 0.3). Furthermore, the woven fabric had complicated voids between the fibers and the hollow portions inside the fibers, and thus had the moderate resilience (bending recovery 2HB: 0.9×10^{-2} gf·cm/cm) and the puffy (apparent density: 0.33 g/cm³) and soft texture (bending hardness B: 0.9×10^{-2} gf·cm²/cm). The woven fabric had excellent stretchability (fabric elongation: 16%) and the water-absorbing quick-drying property (water diffusion time: 25 minutes) due to the presence of the opening portion, and was a woven fabric excellent in wearing comfort in which both texture and function directly linked to the wearing comfort of a person were achieved.

[0155] Further, in the woven fabric, since the opening portion was narrow, the voids in the fiber were maintained without being crushed even after the processing of the woven fabric, the functional agent entering the hollow portion does not fall off by washing or the like when the functional agent was applied, and the performance durability of the functional agent was significantly improved. It is found that the woven fabric also has good wear resistance (frothing: grade 4) without the color deterioration due to the fibrillation caused by the opening portion. The results are shown in the following table.

[Examples 2 and 3]

[0156] Operations were performed according to Example 1, except that the cross-sectional shape was changed to the multi-lobal shape (Example 2) as shown in (b) of FIG. 3 and a flat multi-lobal shape (Example 3) as shown in (c) of FIG. 3.

[0157] In Example 2, by forming the irregularities on the fiber surface, uneven gloss (glare) of the fabric was prevented

by the diffuse reflection of the light, and the water-absorbing quick-drying property was improved by the fine inter-fiber voids.

[0158] In Example 3, since the cross-sectional shape was the combination of the flat shape and the multi-lobal shape, the complicated inter-fiber voids generated by twisting the flat shape and the fine inter-fiber voids in the irregularities on the fiber surface due to the multi-lobal shape were combined to further improve the texture such as a lightweight feel and resilience and the function such as a water-absorbing quick-drying property. The results are shown in the following table.

[Example 4]

[0159] Operation was performed according to Example 1, except that the composite structure was changed to a structure in which the easily soluble polymer was present in the outermost layer as shown in (d) of FIG. 3.

[0160] In Example 4, due to an effect of the inter-fiber voids generated when the easily soluble polymer of the outermost layer was removed, the fibers fixed at binding points of the woven or knitted fabric were movable, thereby improving the flexibility, and the apparent density at the high porosity was reduced, thereby improving the lightweight feel. The results are shown in the following table.

[Examples 5 and 6]

[0161] Operations were performed according to Example 1, except that RB/RA (modification degree), which is the ratio of the inscribed circle diameter RA to the circumscribed circle diameter RB of the fiber, was changed to RB/RA = 1.3 (Example 5) and RB/RA = 1.0 (Example 6) as shown in (c) of FIG. 1.

[0162] In Examples 5 and 6, as the modification degree was reduced, the effect of steric hindrance when twisted was reduced, thereby reducing the roughness, and on the other hand, the crimped form developed by the heat treatment became fine and was approximated to a coil shape, thereby not only increasing the stretchability, but also increasing the fine inter-fiber voids and improving the flexibility. The results are shown in the following table.

[Example 7]

[0163] Operation was performed according to Example 1, except that the cross-sectional shape of the composite fiber was changed to a cross section in which a bonding surface of the polymers having the different melting points and the communication portion were on a straight line, and a direction (angle) of the straight line was random (four types in FIG. 10 are examples of the cross-sectional shape).

[0164] In Example 7, since the crimped form developed by the heat treatment was differs for each single-fiber due to a difference in distance between the centers of gravity, the variation coefficient CV of the rotation angle of the long axis was also increased, the soft tactile sensation was more conspicuous due to the increased roughness, and the lightweight feel was also improved due to the increased inter-fiber voids. The results are shown in the following table.

[Comparative Example 1]

[0165] Operation was performed according to Example 1, except that the polymer 2 was changed to the same PET as the polymer 3.

[0166] In Comparative Example 1, although a certain lightweight feel was obtained by the hollow portion inside the fiber, since the crimped form was not developed, the textile surface had no unevenness feel and lacked the roughness, and since the inter-fiber voids were not developed, the flexibility and the resilience were also lacking. The textile did not have the functions such as a water-absorbing quick-drying property and stretchability. The results are shown in the following table.

[Comparative Example 2]

[0167] Operation was performed according to Comparative Example 1, except that a friction disk was used while heating with a heater set at 180°C between rollers having a processing speed of 250 m/min and a stretching ratio of 1.05 times after stretching, and the false twisting was performed at a rotation speed at which the number of false twists became 3,000 T/m.

[0168] In Comparative Example 2, although the crimped form was obtained by the false twisting, the irregularities of the textile surface was monotonous, and the roughness was lacking. The results are shown in the following table.

[Comparative Example 3]

[0169] Operation was performed according to Example 1, except that the composite structure was changed to a structure as shown in (b) of FIG. 4, in which circular hardly soluble polymers having different melting points were laminated in a direction from the fiber center toward the fiber surface.

[0170] In Comparative Example 2, although a certain lightweight feel was obtained by forming the void inside the fiber by removing the easily soluble polymer of the innermost layer, the hardly soluble polymers having the different melting points were not unevenly distributed and the crimped form by the heat treatment was hardly developed, and thus in addition to the lack of the flexibility, the resilience, and the roughness, the textile did not have the functions such as a water-absorbing quick-drying property and stretchability. The results are shown in the following table.

[Comparative Example 4]

[0171] As the polymer 2, polyethylene terephthalate (IPA-copolymerized PET, melt viscosity: 140 Pa s, melting point: 232°C) copolymerized with 7 mol% of isophthalic acid was prepared, and as the polymer 3, polyethylene terephthalate (PET, melt viscosity: 130 Pa-s, melting point: 254°C) was prepared.

[0172] After these polymers were separately melted at 290°C, the polymer 2/polymer 3 were weighed such that a weight ratio of the polymer 2/polymer 3 was 50/50, and inflowing polymers were discharged from the discharge holes so as to form the hollow composite fiber as shown in (a) of FIG. 4, which has a composite structure in which the hollow ratio was 20%, and the polymer 2 and the polymer 3 were bonded in a side-by-side manner.

[0173] After cooling and solidifying, the oil agent was applied to the discharged composite polymer flow, and the composite polymer flow was wound at the spinning speed of 1,500 m/min, and stretched between the rollers heated to 90°C and 130°C to produce a composite fiber having 56 dtex-36 filaments (fiber diameter: 13 μm).

[0174] The obtained composite fiber was woven, subjected to the scouring treatment at 80°C and the wet heat treatment at 130°C, and then subjected to the heat setting at 180°C to obtain the woven fabric formed by the composite fiber.

[0175] In Comparative Example 4, since the inside of the fiber was already hollow during the production of the fiber, the hollow portion was crushed by the crimp-developing in the weaving process or the heat treatment, and when the woven fabric was formed, the lightweight feel was impaired, and the flexibility and the resilience were lacking. The results are shown in the following table.

[Examples 8 and 9]

[0176] Operations were performed according to Example 1, except that the communication width made of the easily soluble polymer was changed to 8% (Example 8) and 16% (Example 9) with respect to the fiber diameter.

[0177] In Examples 8 and 9, as the opening portion formed after the removal of the easily soluble polymer became larger, the friction coefficient increased due to the opening portion being caught by a finger when the opening portion was touched by a hand, and the water-absorbing quick-drying property was improved due to the increase in surface area of the fiber in contact with a water droplet when the water droplet was dropped. The results are shown in the following table.

[Examples 10 and 11]

[0178] Operations were performed according to Example 1, except that the weight ratio of the polymer 2/polymer 3 was changed to 60/20 (Example 10) and 20/60 (Example 11).

[0179] In Examples 10 and 11, as a ratio of the polymer 2 on a high shrinkage side was increased, the crimped form was more strongly developed, and the lightweight feel of the obtained woven fabric was increased. As an amount of the polymer 3, which is a low shrinkage component, was increased, clogging due to a high shrinkage ratio on the high shrinkage side in the heat setting was prevented, and the flexibility was excellent. The results are shown in the following table.

[Examples 12 and 13]

[0180] Operations were performed according to Example 1, except that a weight ratio of the polymer 1/polymer 2/polymer 3 was changed to 10/45/45 (Example 12) and 30/35/35 (Example 13).

[0181] In Examples 12 and 13, when the hollow ratio was decreased by decreasing the weight ratio of the polymer 3, since the bending hardness was increased, a characteristic elastic tactile sensation could be obtained. When the hollow ratio was increased by increasing the weight ratio of the polymer 3, an amount of air contained in the fiber was increased, and thus the lightweight feel was increased, and the flexibility and the resilience were excellent. The results are shown

in the following table.

[Examples 14 and 15]

[0182] Operations were performed according to Example 1, except that the discharge amount was changed such that the fiber diameter was 17 μm (Example 14) and 24 μm (Example 15).

[0183] In Examples 14 and 15, by increasing the fiber diameter, a loop of the crimped form developed by the heat treatment was increased, the roughness and the lightweight feel were improved, and the bending hardness was increased, and thus the characteristic elastic tactile sensation was obtained. The results are shown in the following table.

[Example 16]

[0184] Operation was performed according to Example 1 except that the polymer 3 was changed to polyethylene terephthalate (TiO_2 -containing PET) containing 5.0% by mass of titanium oxide.

[0185] In Example 16, when the easily soluble polymer was removed, since titanium oxide deposited on the surface of the polymer 3 also falls off, the irregularities were formed on the surface, and thus in addition to improving the appearance of the fabric by preventing the increase or decrease in reflection (glare) depending on the incident angle of the light by diffusely reflecting the light, the functionality such as anti-transparency and ultraviolet shielding due to titanium oxide inside the fiber was obtained. The results are shown in the following table.

[Example 17]

[0186] Operation was performed according to Example 1 except that the polymer 2 was changed to polypropylene terephthalate (PPT).

[0187] In Example 17, due to a property of rubber elasticity of PPT, the lightweight feel and the excellent flexible texture were developed, and a stretching function was also significantly improved. Since PPT had a low refractive index as compared with PET, the obtained woven fabric was also excellent in color development property. The results are shown in the following table.

[Example 18]

[0188] Polyethylene terephthalate (SSIA-PEG copolymer PET, melt viscosity: 100 Pa·s, melting point: 233°C) obtained by copolymerizing 8 mol% of 5-sodium sulfoisophthalic acid and 9 mass% of polyethylene glycol as the polymer 1, nylon 6-nylon 66 copolymer (N6-66 copolymer, melt viscosity: 240 Pa s, melting point: 195°C) as the polymer 2, and nylon 6 (N6, melt viscosity: 190 Pa·s, melting point: 223°C) as the polymer 3 were prepared.

[0189] These polymers were separately melted at 280°C, and then the polymer 1/polymer 2/polymer 3 were weighed such that the weight ratio of the polymer 1/polymer 2/polymer 3 was 20/40/40 and flowed into the spin pack in which the composite spinneret shown in FIG. 5 was incorporated. Inflowing polymers were discharged from the discharge holes so as to form the flat composite fiber as shown in (a) of FIG. 2, which has a composite structure in which the polymer 1 was disposed in the innermost layer, and the polymer 2 and the polymer 3 were joined to the outermost layer in the side-by-side manner.

[0190] After cooling and solidifying, the oil agent was applied to the discharged composite polymer flow, and the composite polymer flow was wound at the spinning speed of 1,500 m/min, and stretched between the rollers heated to 90°C and 130°C to produce a composite fiber having 56 dtex-36 filaments (fiber diameter: 12 μm).

[0191] The obtained composite fiber was woven, subjected to the scouring treatment at 80°C and the wet heat treatment at 130°C, and then treated in a 1% by mass of sodium hydroxide aqueous solution (bath ratio: 1:50) heated to 90°C to remove 99% or more of the polymer 1 as the easily soluble polymer. Thereafter, the heat setting was added at 180°C to obtain a woven fabric formed by a multifilament including flat hollow fibers having flatness of 1.8, a hollow ratio of 20%, and the number of crimped peaks of 12 peaks/cm as shown in (a) of FIG. 6.

[0192] In Example 18, due to a property of nylon having low density and low elasticity as compared with polyester, excellent lightweight feel was obtained, and more flexible texture was developed. The results are shown in the following table.

[Table 1]

		Example 1	Example 2	Example 3	Example 4
5 10 15	Polymer	Polymer 1	SSIA-PEG copolymer PET	SSIA-PEG copolymer PET	SSIA-PEG copolymer PET
		Polymer 2	IPA- copolymerized PET	IPA- copolymerized PET	IPA- copolymerized PET
		Polymer 3	PET	PET	PET
		(Melting point of polymer 3) - (melting point of polymer 2)	22°C	22°C	22°C
		Weight ratio (polymer 1/2/3)	20/40/40	20/40/40	30/35/35
20 25	Composite fiber	Cross-sectional shape	Flat	Multi-lobal	Flat multi-lobal
		Composite structure	(a) of FIG. 3	(b) of FIG. 3	(c) of FIG. 3
		Modification degree (RB/RA)	1.8	1.2	1.7
		Communication width (μm)	0.5	0.3	0.4
		Fiber diameter (μm)	12	12	12
		Ratio of communication width to fiber diameter (%)	4	3	4
30 35 40	Hollow fiber	Cross-sectional shape	(b) of FIG. 6	(b) of FIG. 7	(c) of FIG. 6
		Flatness	1.8	1.0	1.7
		Hollow ratio (%)	18	18	18
		Width of opening portion (μm)	0.5	0.4	0.4
		Fiber diameter (μm)	12	12	12
		Ratio of opening portion to fiber diameter (%)	4	3	4
		Number of crimped peaks (peaks/cm)	17	19	17
45	Multifilament	Variation coefficient CV of rotation angle of long axis (%)	27	-	25
50					
55					

[Table 2]

		Example 5	Example 6	Example 7	Comparative Example 1
5	Polymer	Polymer 1	SSIA-PEG copolymer PET	SSIA-PEG copolymer PET	SSIA-PEG copolymer PET
10		Polymer 2	IPA-copolymerized PET	IPA-copolymerized PET	PET
15		Polymer 3	PET	PET	PET
		(Melting point of polymer 3) - (melting point of polymer 2)	22°C	22°C	0°C
		Weight ratio (polymer 1/2/3)	20/40/40	20/40/40	20/40/40
20	Composite fiber	Cross-sectional shape	Flat	Round	Flat
		Composite structure	(a) of FIG. 3	(c) of FIG. 1	FIG. 10
25		Modification degree (RB/RA)	1.3	1.0	1.8
		Communication width (μm)	0.4	0.4	0.4
30		Fiber diameter (μm)	12	12	12
		Ratio of communication width to fiber diameter (%)	4	3	3
35	Hollow fiber	Cross-sectional shape	(b) of FIG. 6	(a) of FIG. 7	FIG. 9
		Flatness	1.3	1.0	1.8
		Hollow ratio (%)	18	18	18
		Width of opening portion (μm)	0.4	0.4	0.4
40		Fiber diameter (μm)	12	12	12
		Ratio of opening portion to fiber diameter (%)	4	3	3
		Number of crimped peaks (peaks/cm)	19	21	12
45	Multifilament	Variation coefficient CV of rotation angle of long axis (%)	31	-	38
50					6

50

55

[Table 3]

		Comparative Example 2	Comparative Example 3	Comparative Example 4	Example 8
Polymer	Polymer 1	SSIA-PEG copolymer PET	SSIA-PEG copolymer PET	-	SSIA-PEG copolymer PET
	Polymer 2	PET	IPA- copolymerized PET	IPA- copolymerized PET	IPA- copolymerized PET
	Polymer 3	PET	PET	PET	PET
	(Melting point of polymer 3) - (melting point of polymer 2)	0°C	22°C	22°C	22°C
	Weight ratio (polymer 1/2/3)	20/40/40	20/40/40	20/40/40	20/40/40
Composite fiber	Cross-sectional shape	Flat	Round	Round	Flat
	Composite structure	(a) of FIG. 3	(b) of FIG. 4	(a) of FIG. 4	(a) of FIG. 3
	Modification degree (RB/RA)	1.8	1.0	1.8	1.8
	Communication width (μm)	0.5	0.4	-	1.0
	Fiber diameter (μm)	12	12	13	12
	Ratio of communication width to fiber diameter (%)	4	3	-	8
Hollow fiber	Cross-sectional shape	(b) of FIG. 6	FIG. 8	(a) of FIG. 4	(b) of FIG. 6
	Flatness	1.8	1.0	1.0	1.8
	Hollow ratio (%)	18	18	20	16
	Width of opening portion (μm)	0.5	0.4	-	1.0
	Fiber diameter (μm)	12	12	12	12
	Ratio of opening portion to fiber diameter (%)	4	3	-	8
	Number of crimped peaks (peaks/cm)	54	0	23	17
Multifilament	Variation coefficient CV of rotation angle of long axis (%)	69	-	-	26

[Table 4]

		Example 9	Example 10	Example 11	Example 12
5 10 15	Polymer	Polymer 1	SSIA-PEG copolymer PET	SSIA-PEG copolymer PET	SSIA-PEG copolymer PET
		Polymer 2	IPA- copolymerized PET	IPA- copolymerized PET	IPA- copolymerized PET
		Polymer 3	PET	PET	PET
		(Melting point of polymer 3) - (melting point of polymer 2)	22°C	22°C	22°C
		Weight ratio (polymer 1/2/3)	20/40/40	20/60/20	20/20/60
20 25	Composite fiber	Cross-sectional shape	Flat	Flat	Flat
		Composite structure	(a) of FIG. 3	(a) of FIG. 3	(a) of FIG. 3
		Modification degree (RB/RA)	1.8	1.8	1.8
		Communication width (μm)	1.9	0.5	0.5
		Fiber diameter (μm)	12	12	12
		Ratio of communication width to fiber diameter (%)	16	4	4
30 35 40	Hollow fiber	Cross-sectional shape	(b) of FIG. 6	(b) of FIG. 6	(b) of FIG. 6
		Flatness	1.8	1.8	1.8
		Hollow ratio (%)	12	18	18
		Width of opening portion (μm)	1.9	0.5	0.5
		Fiber diameter (μm)	12	12	12
		Ratio of opening portion to fiber diameter (%)	16	4	4
		Number of crimped peaks (peaks/cm)	17	22	7
45	Multifilament	Variation coefficient CV of rotation angle of long axis (%)	27	41	11
					33

[Table 5]

		Example 13	Example 14	Example 15	Example 16
5 10 15	Polymer	Polymer 1	SSIA-PEG copolymer PET	SSIA-PEG copolymer PET	SSIA-PEG copolymer PET
		Polymer 2	IPA-copolymerized PET	IPA-copolymerized PET	IPA-copolymerized PET
		Polymer 3	PET	PET	PET
		(Melting point of polymer 3) - (melting point of polymer 2)	22°C	22°C	22°C
		Weight ratio (polymer 1/2/3)	30/35/35	20/40/40	20/40/40
20 25 30	Composite fiber	Cross-sectional shape	Flat	Flat	Flat
		Composite structure	(a) of FIG. 3	(a) of FIG. 3	(a) of FIG. 3
		Modification degree (RB/RA)	1.8	1.8	1.8
		Communication width (μm)	0.8	0.7	1.0
		Fiber diameter (μm)	12	17	24
		Ratio of communication width to fiber diameter (%)	7	4	4
35 40	Hollow fiber	Cross-sectional shape	(b) of FIG. 6	(b) of FIG. 6	(b) of FIG. 6
		Flatness	1.8	1.8	1.8
		Hollow ratio (%)	27	18	18
		Width of opening portion (μm)	0.8	0.7	1.0
		Fiber diameter (μm)	12	17	24
		Ratio of opening portion to fiber diameter (%)	6	4	4
		Number of crimped peaks (peaks/cm)	15	12	10
45	Multifilament	Variation coefficient CV of rotation angle of long axis (%)	25	18	16
					27

[Table 6]

		Example 17	Example 18
5 10	Polymer	Polymer 1	SSIA-PEG copolymer PET
		Polymer 2	PPT
		Polymer 3	PET
		(Melting point of polymer 3) - (melting point of polymer 2)	21°C
		Weight ratio (polymer 1/2/3)	20/40/40
15 20	Composite fiber	Cross-sectional shape	Flat
		Composite structure	(a) of FIG. 3
		Modification degree (RB/RA)	1.8
		Communication width (μm)	0.5
		Fiber diameter (μm)	12
		Ratio of communication width to fiber diameter (%)	4
25 30	Hollow fiber	Cross-sectional shape	(b) of FIG. 6
		Flatness	1.8
		Hollow ratio (%)	17
		Width of opening portion (μm)	1
		Fiber diameter (μm)	12
		Ratio of opening portion to fiber diameter (%)	4
		Number of crimped peaks (peaks/cm)	24
35	Multifilament	Variation coefficient CV of rotation angle of long axis (%)	45

[Table 7]

		Example 1	Example 2	Example 3	Example 4
40 45 50	Texture evaluation	Lightweight Feel (apparent density (g/cm ³))	A (0.33)	A (0.34)	A (0.31)
		Flexibility (bending hardness B × 10 ⁻² (gf·cm ² /cm))	A (0.9)	A (0.8)	A(0.9)
		Resilience (bending recovery 2HB × 10 ⁻² (gf·cm/cm))	A (0.9)	A (1.0)	A (0.8)
		Smoothness (friction coefficient)	A (0.3)	B (0.6)	B (0.7)
		Roughness (friction fluctuation × 10 ⁻²)	A (0.9)	B (0.5)	A (0.9)
55	Function evaluation	Water-absorbing quick-drying property (water diffusion time (minutes))	B (25)	A(20)	A (15)
		Stretchability (fabric elongation (%))	A (16)	A (17)	A (16)
	Wear resistance	A (grade 4)	A (grade 4)	A (grade 4)	A (grade 4)

[Table 8]

		Example 5	Example 6	Example 7	Comparative Example 1
Texture evaluation	Lightweight Feel (apparent density (g/cm³))	B (0.36)	B (0.38)	A (0.30)	B (0.44)
	Flexibility (bending hardness $B \times 10^{-2}$ (gf·cm²/cm))	A (0.8)	A (0.7)	A (0.8)	C (2.8)
	Resilience (bending recovery 2HB $\times 10^{-2}$ (gf·cm/cm))	B (1.1)	B (1.2)	A (1.0)	C (2.7)
	Smoothness (friction coefficient)	A (0.4)	B (0.5)	A (0.3)	A (0.2)
	Roughness (friction fluctuation $\times 10^{-2}$)	B (0.7)	B (0.5)	A (1.1)	C (0.2)
Function evaluation	Water-absorbing quick-drying property (water diffusion time (minutes))	B (25)	B (30)	A(20)	C (45)
	Stretchability (fabric elongation (%))	A (20)	A (24)	B (13)	C(0)
Wear resistance		A (grade 4)	A (grade 4)	A (grade 4)	A (grade 4)

[Table 9]

		Comparative Example 2	Comparative Example 3	Comparative Example 4	Example 8
Texture evaluation	Lightweight Feel (apparent density (g/cm ³))	A (0.32)	B (0.44)	C (0.48)	B (0.36)
	Flexibility (bending hardness B × 10 ⁻² (gf·cm ² /cm))	A (0.8)	C (2.6)	C (2.0)	B (1.1)
	Resilience (bending recovery 2HB × 10 ⁻² (gf·cm/cm))	B (1.1)	C (2.4)	C (2.0)	B (1.3)
	Smoothness (friction coefficient)	B (0.8)	B (0.3)	B (0.5)	B (0.6)
	Roughness (friction fluctuation × 10 ⁻²)	C (0.4)	C (0.2)	B (0.5)	A(0.9)
Function evaluation	Water-absorbing quick-drying property (water diffusion time (minutes))	B (25)	C (45)	B (30)	B (25)
	Stretchability (fabric elongation (%))	B (10)	C (0)	A (17)	B (14)
Wear resistance		A (grade 4)	A (grade 4)	A (grade 4.5)	B (grade 3.5)

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[Table 10]

		Example 9	Example 10	Example 11	Example 12
Texture evaluation	Lightweight Feel (apparent density (g/cm ³))	B (0.42)	B (0.38)	B (0.4)	B (0.38)
	Flexibility (bending hardness B × 10 ⁻² (gf·cm ² /cm))	B (1.8)	B (1.9)	A (0.8)	B (1.3)
	Resilience (bending recovery 2HB × 10 ⁻² (gf·cm/cm))	B (1.9)	B (1.6)	B (1.2)	B (1.4)
	Smoothness (friction coefficient)	B (1.0)	A (0.3)	A (0.3)	A (0.3)
	Roughness (friction fluctuation × 10 ⁻²)	A(0.9)	B (0.6)	B (0.6)	A(0.9)
Function evaluation	Water-absorbing quick-drying property (water diffusion time (minutes))	A (20)	B (25)	B (35)	B (25)
	Stretchability (fabric elongation (%))	B (10)	B (14)	B (5)	A (16)
Wear resistance		B (grade 3)	A (grade 4)	A (grade 4)	A (grade 4.5)

[Table 11]

		Example 13	Example 14	Example 15	Example 16
Texture evaluation	Lightweight Feel (apparent density (g/cm ³))	A (0.33)	A (0.31)	A (0.29)	A (0.33)
	Flexibility (bending hardness B × 10 ⁻² (gf·cm ² /cm))	A (0.9)	B (1.2)	B (1.8)	A (0.9)
	Resilience (bending recovery 2HB × 10 ⁻² (gf·cm/cm))	A (0.6)	A (0.8)	A (0.6)	A (0.9)
	Smoothness (friction coefficient)	A (0.3)	B (0.5)	B (0.7)	B (0.4)
	Roughness (friction fluctuation × 10 ⁻²)	A (0.9)	A (1.0)	A (1.1)	A (0.9)
Function evaluation	Water-absorbing quick-drying property (water diffusion time (minutes))	B (25)	B (25)	B (30)	B (25)
	Stretchability (fabric elongation (%))	B (13)	B (14)	B (12)	A (16)
Wear resistance		B (grade 3.5)	A (grade 4)	A (grade 4)	A (grade 4)

[Table 12]

		Example 17	Example 18
Texture evaluation	Lightweight Feel (apparent density (g/cm ³))	A (0.31)	A (0.28)
	Flexibility (bending hardness B × 10 ⁻² (gf·cm ² /cm))	A (0.6)	A (0.6)
	Resilience (bending recovery 2HB × 10 ⁻² (gf·cm/cm))	B (1.6)	B (2.0)
	Smoothness (friction coefficient)	B (0.5)	B (0.5)
	Roughness (friction fluctuation × 10 ⁻²)	B (0.6)	B (0.8)

(continued)

		Example 17	Example 18
Function evaluation	Water-absorbing quick-drying property (water diffusion time (minutes))	A (20)	B (35)
	Stretchability (fabric elongation (%))	A (27)	B (14)
Wear resistance		A (grade 4)	B (grade 3.5)

[0193] Meanings of abbreviations in the tables are as follows.

PET: polyethylene terephthalate
 PEG: polyethylene glycol
 SSIA: 5-sodium sulfoisophthalic acid
 IPA: isophthalic acid
 PPT: polypropylene terephthalate
 N6: nylon 6
 N6-66 copolymer: nylon 6-nylon 66 copolymer
 TiO₂: titanium oxide

[0194] Although the present invention has been described in detail with reference to specific embodiments, it will be apparent to those skilled in the art that various modifications and variations are possible without departing from the spirit and scope of the present invention. The present application is based on Japanese Patent Application (Patent Application No. 2020-137899) filed on August 18, 2020 and Japanese Patent Application (Patent Application No. 2020-194085) filed on November 24, 2020, contents of which are incorporated herein by reference.

INDUSTRIAL APPLICABILITY

[0195] In a composite fiber, a hollow fiber, and a multifilament according to the present invention, void structures inside and between fibers are finely controlled, whereby a textile excellent in wearing comfort, which achieves moderate resilience and a puffy and soft texture, can be obtained. Accordingly, the composite fiber, the hollow fiber, and the multifilament according to the present invention can be suitably used for a wide variety of fiber products, from general clothing such as jackets, skirts, pants, and underwear, to interior products such as carpets and sofas, vehicle interior products such as car seats, home applications such as cosmetics, cosmetic masks, and health products in addition to sports clothing and clothing materials, taking advantage of comfortability thereof.

REFERENCE SIGNS LIST

[0196]

x: easily soluble polymer
 y: hardly soluble polymers on low melting point side
 z: hardly soluble polymers on high melting point side
 a1 and a2: intersection of fiber surface and inscribed circle
 b1 and b2: intersection of fiber surface and circumscribed circle
 c1 and c2: two points farthest from each other on fiber outer periphery
 d1 and d2: intersection of straight line passing through midpoint of straight line connecting two points farthest from each other and fiber surface on fiber outer periphery
 A: circle inscribed at least two points with fiber surface, present only inside fiber, and having maximum possible diameter within range in which circumference of inscribed circle and fiber surface do not intersect
 B: circle circumscribing fiber surface at least two points, present only inside fiber, and having minimum possible diameter within range in which circumference of circumscribed circle and fiber surface do not intersect
 G: fiber center
 H: hollow portion
 I: among straight lines that pass through fiber center and equally divide fiber cross section into two, straight line dividing fiber cross section such that area ratio of hardly soluble polymer on high melting point side and hardly soluble polymer on low melting point side in fiber cross sections on left and right sides or upper and lower sides is

in range of 100:0 to 70:30 in either fiber cross section and in range of 30:70 to 0: 100 in the other fiber cross section

S: straight line passing through fiber center G and parallel to communication portion

W: width of communication portion perpendicular to straight line S

S': straight line passing through fiber center G and parallel to opening portion

W': width of opening portion perpendicular to straight line S'

1: measuring plate

2: distribution plate

3: discharge plate

Claims

1. A composite fiber comprising:

two or more kinds of polymers that have different dissolution rates in a solvent and are laminated in a direction from a fiber center to a fiber surface in a fiber cross section, wherein an innermost layer including the fiber center comprises an easily soluble polymer, and two kinds of hardly soluble polymers having different melting points are unevenly distributed in at least one layer other than the innermost layer.

2. The composite fiber according to claim 1, wherein

a relationship between an inscribed circle diameter RA and a circumscribed circle diameter RB of the fiber is $1.2 \leq RB/RA \leq 2.4$ in the fiber cross section.

3. The composite fiber according to claim 1 or 2, wherein

in the fiber cross section, the easily soluble polymer communicates from the fiber center to the fiber surface, and a communication width is 10% or less of a fiber diameter.

4. The composite fiber according to any one of claims 1 to 3, wherein

in the fiber cross section, an outermost layer comprises the easily soluble polymer.

5. A hollow fiber obtained by removing the easily soluble polymer from the composite fiber according to any one of claims 1 to 4.

6. A multifilament comprising:

a flat hollow fiber, wherein

a variation coefficient CV of a rotation angle of a long axis of the flat hollow fiber is 15% to 50%.

7. The multifilament according to claim 6, wherein

the flat hollow fiber has a flatness of 1.2 or more in a fiber cross section.

8. The multifilament according to claim 6 or 7, wherein

the flat hollow fiber is made of at least two kinds of polymers having different melting points in a fiber cross section.

9. The multifilament according to any one of claims 6 to 8, wherein

the flat hollow fiber includes an opening portion formed in a direction from a fiber center to a fiber surface, and a width of the opening portion is 10% or less of a fiber diameter.

10. A fiber product partially comprising:

the composite fiber according to any one of claims 1 to 4, the hollow fiber according to claim 5, or the multifilament according to any one of claims 6 to 9.

FIG. 1

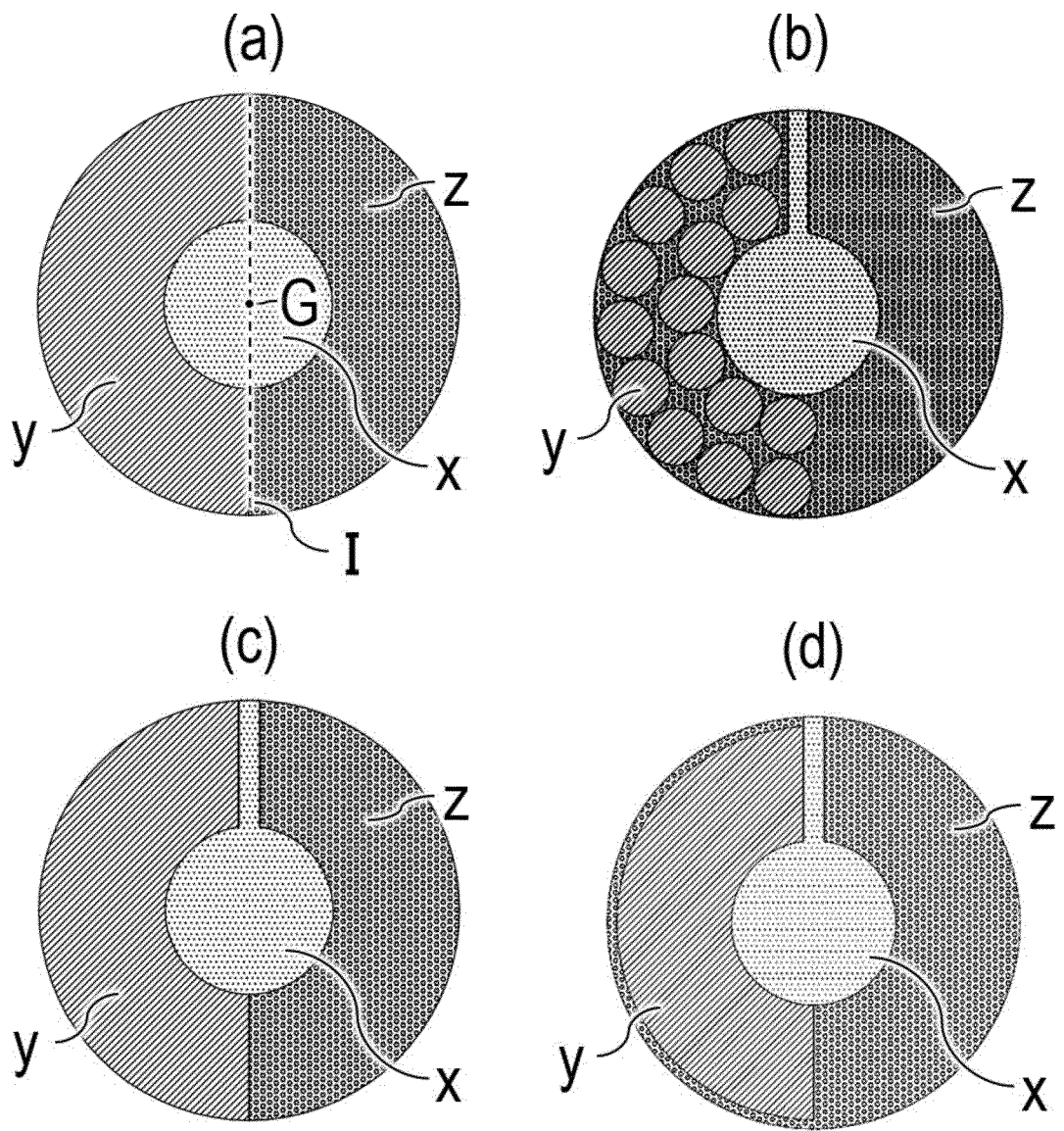


FIG. 2

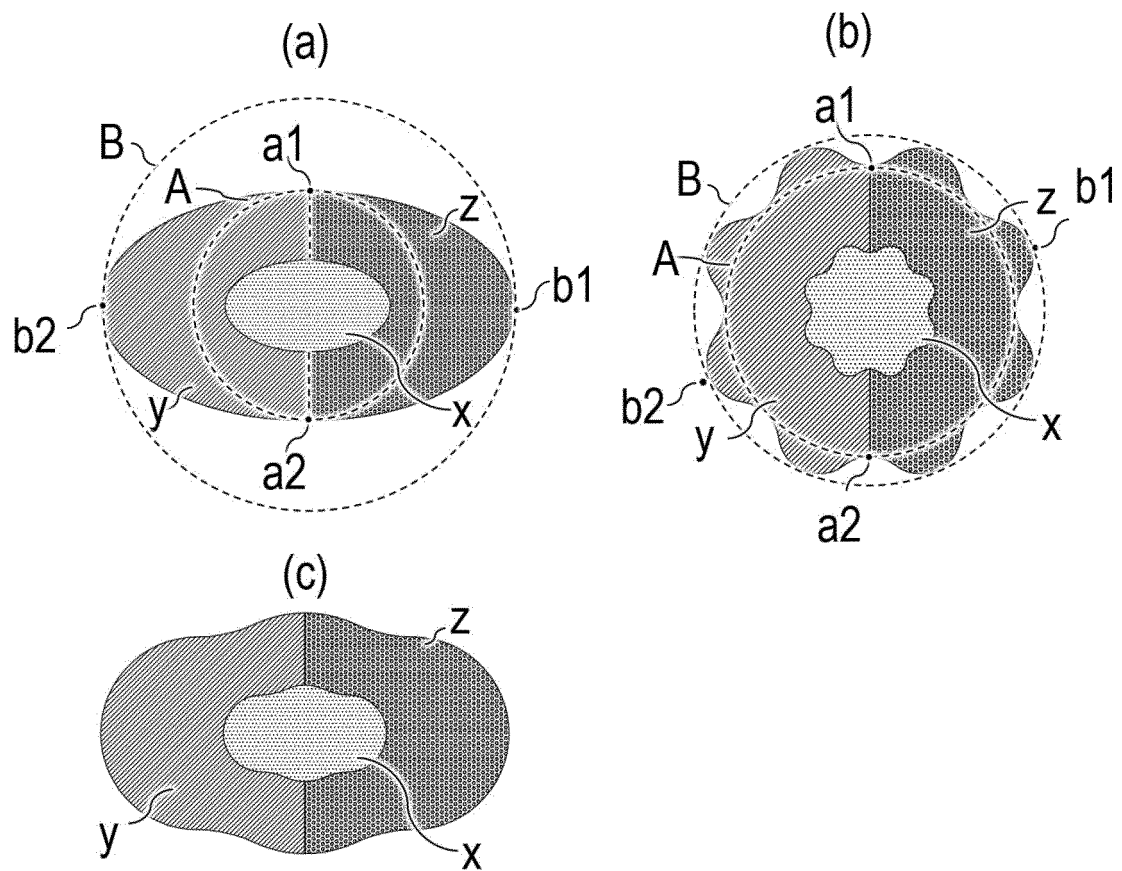


FIG. 3

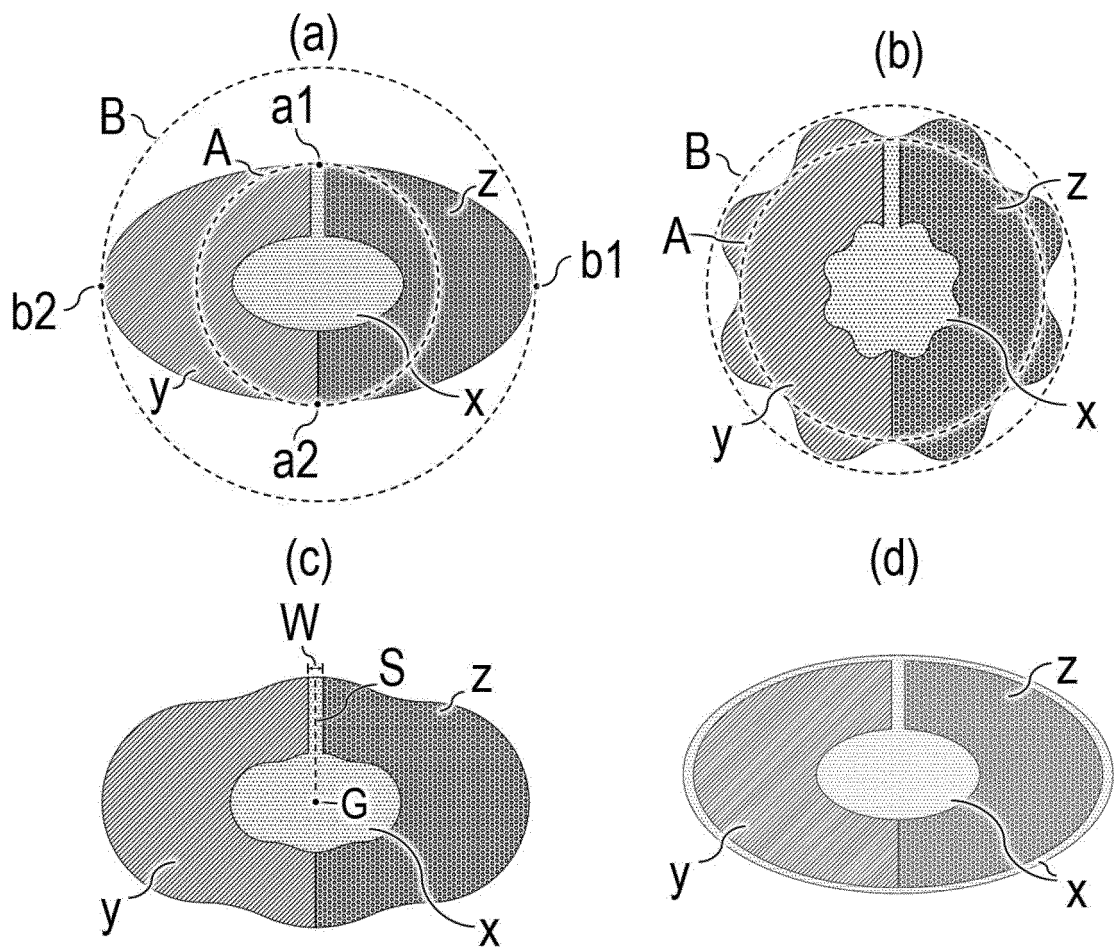


FIG. 4

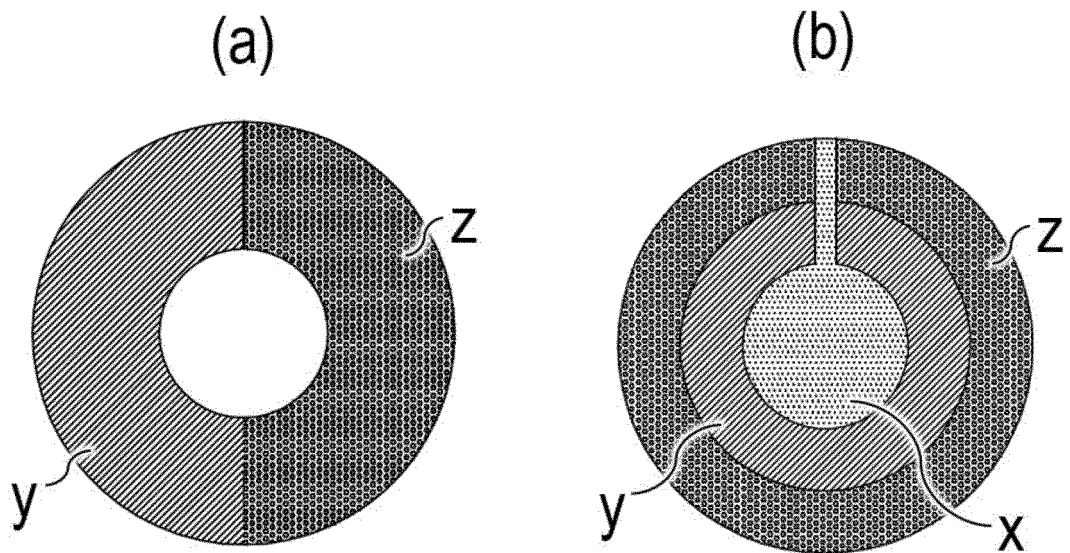


FIG. 5

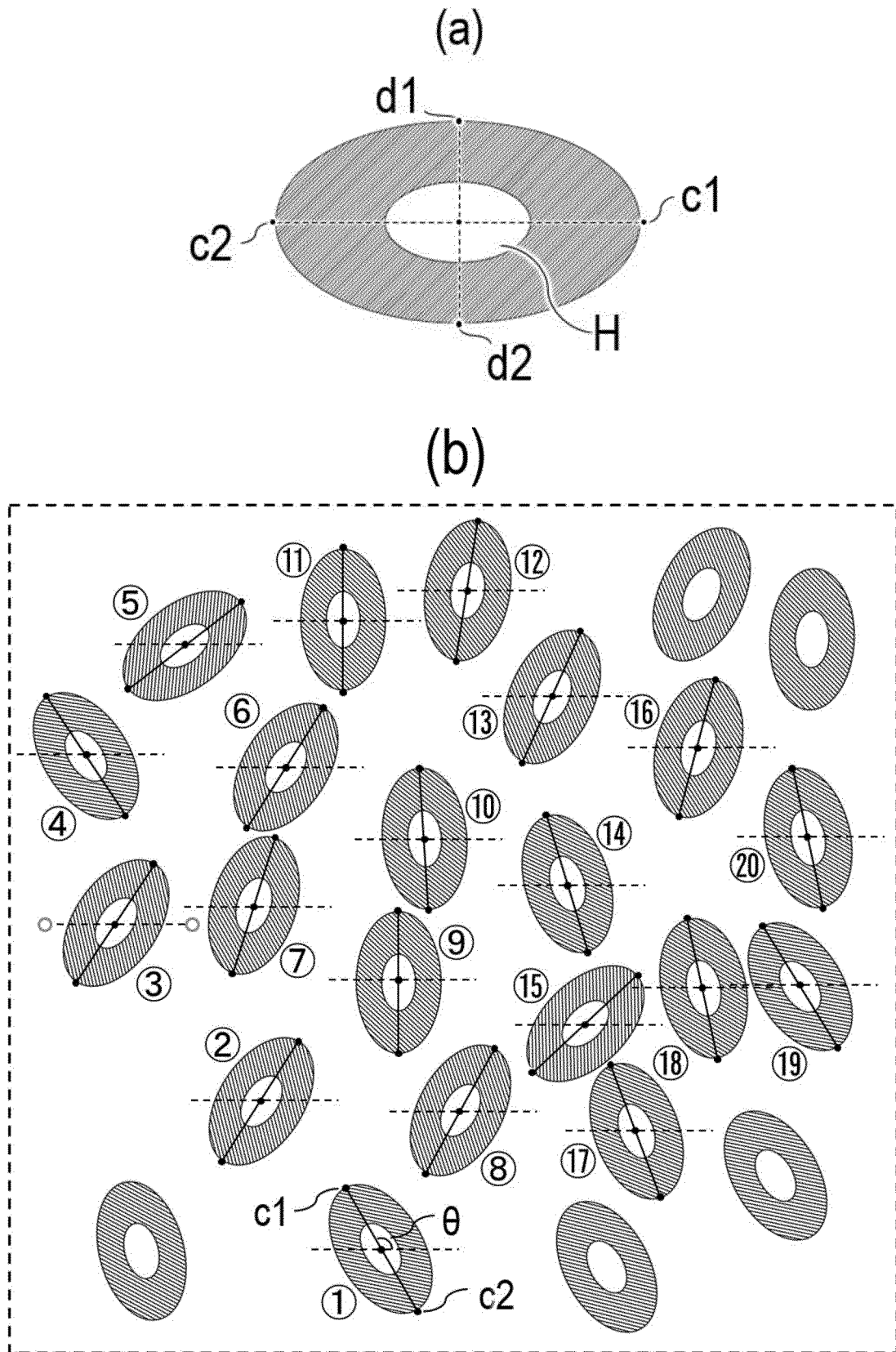


FIG. 6

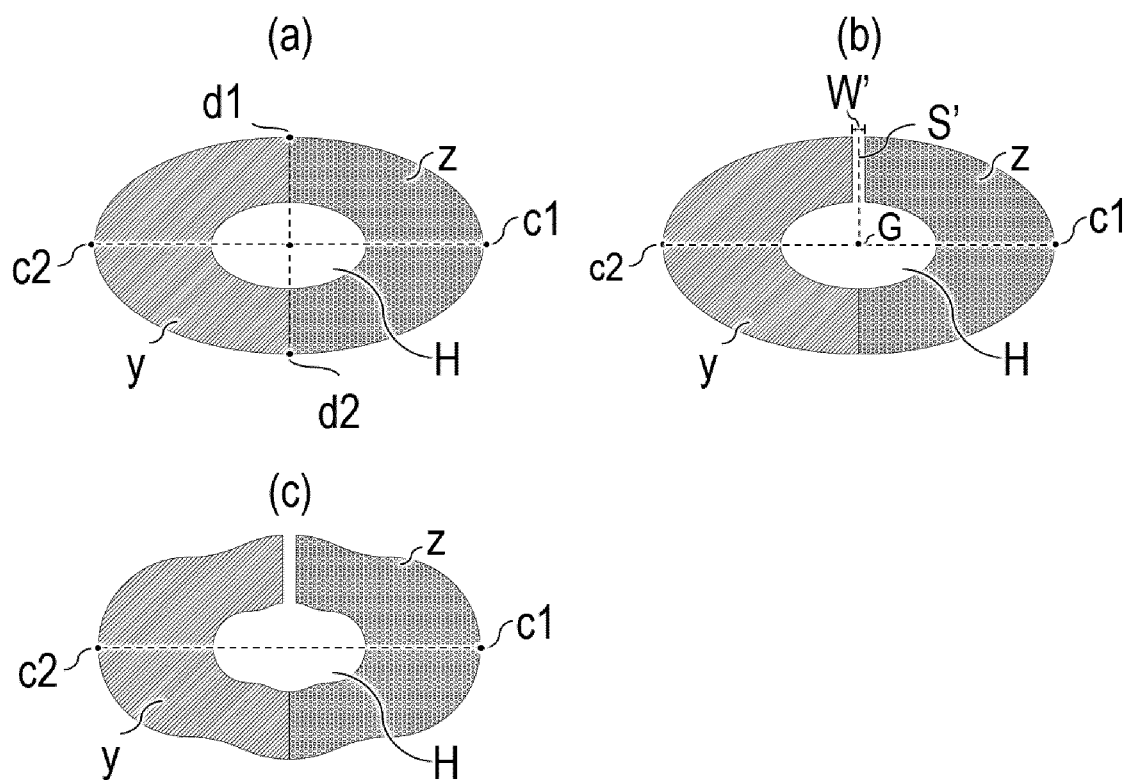


FIG. 7

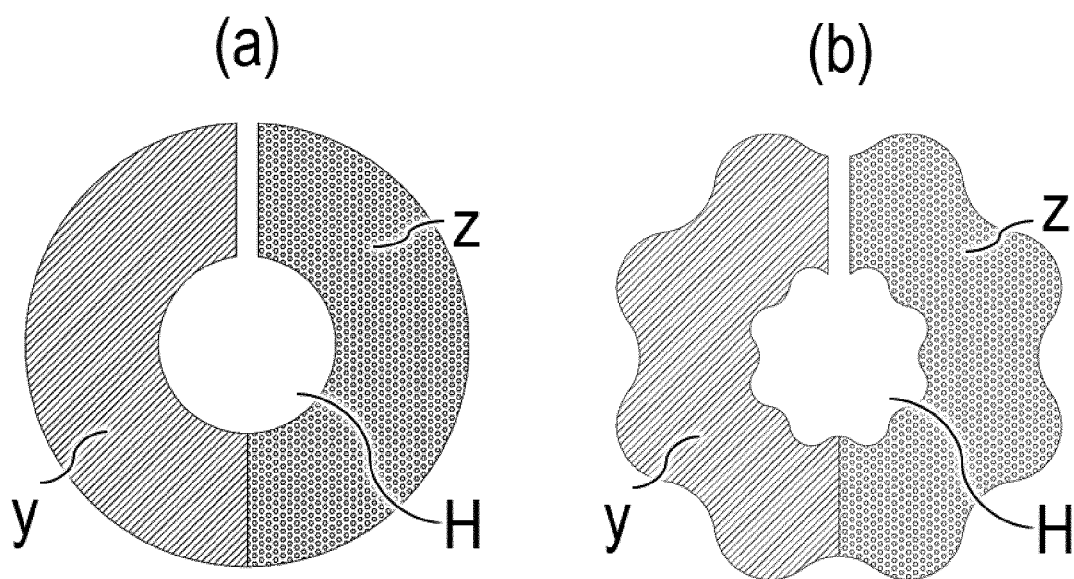


FIG. 8

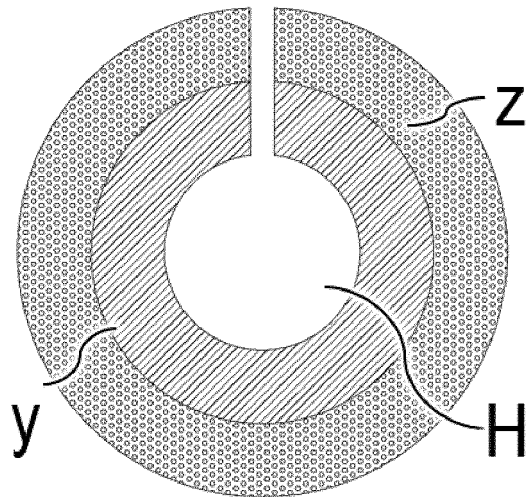


FIG. 9

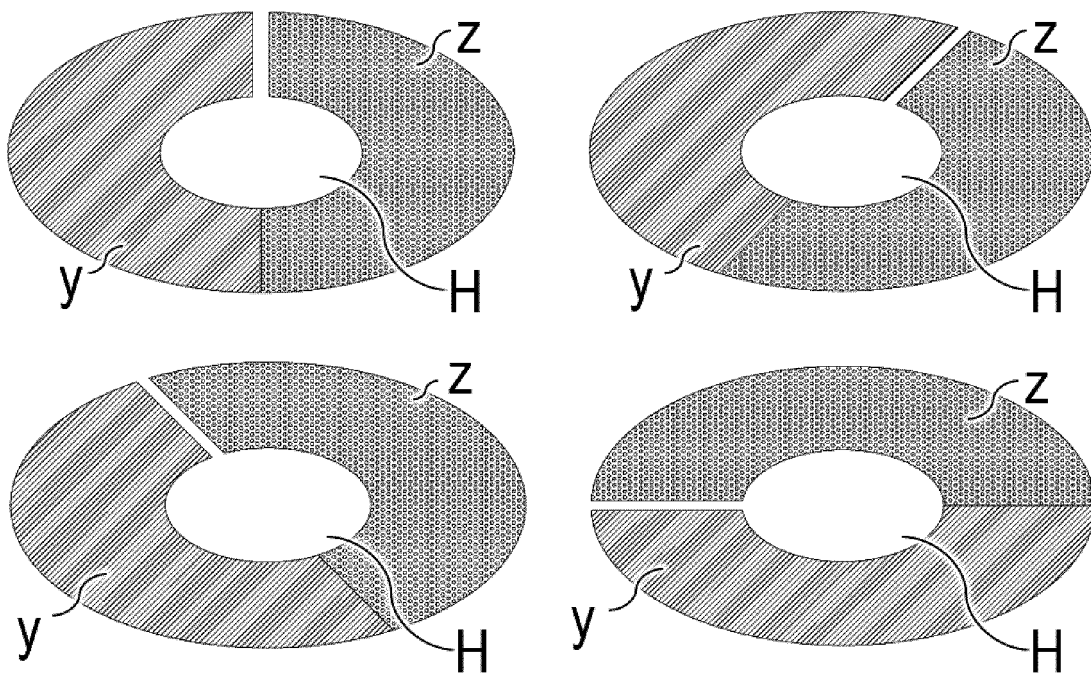


FIG. 10

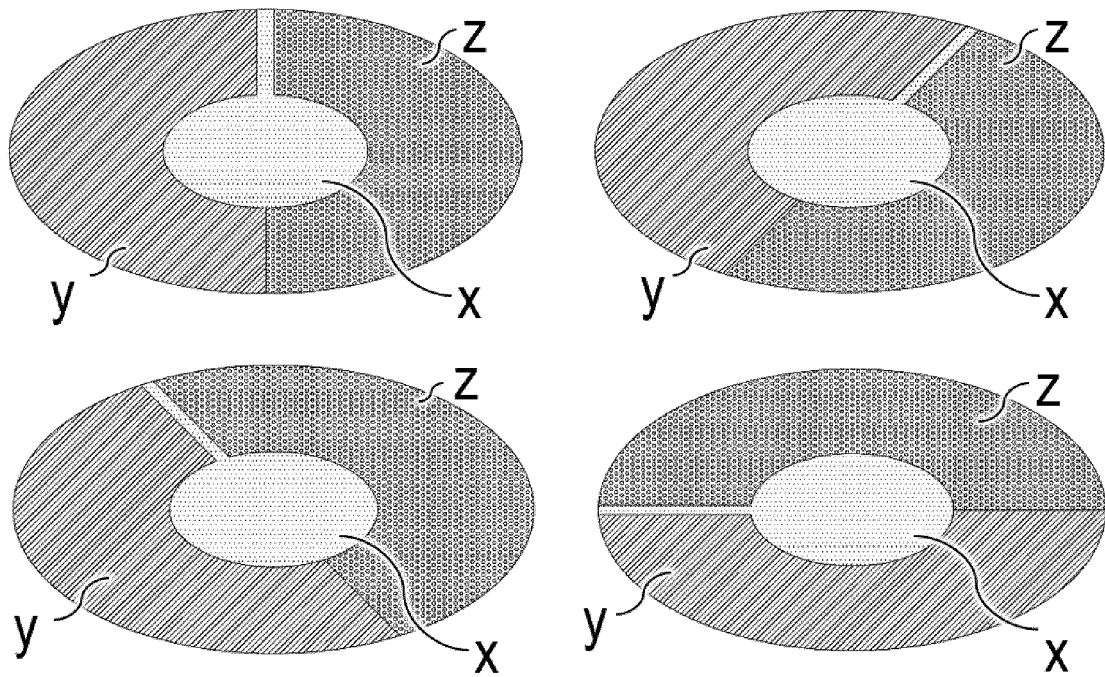


FIG. 11

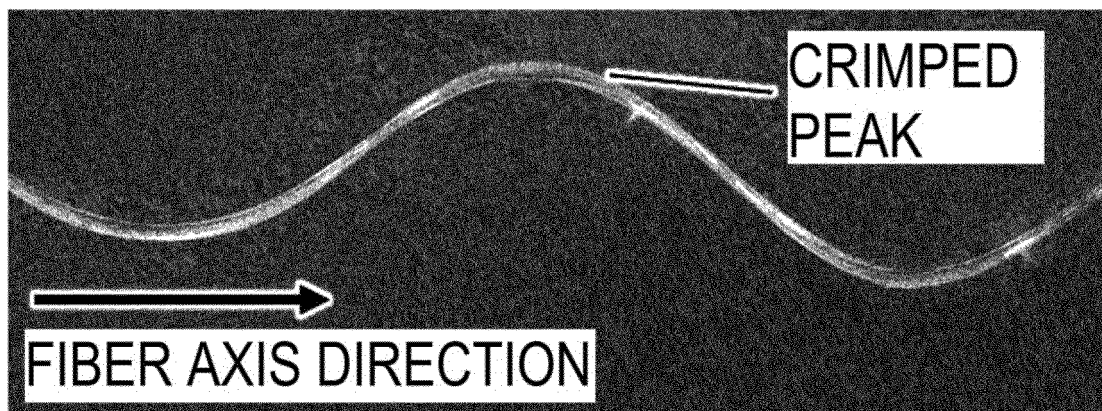
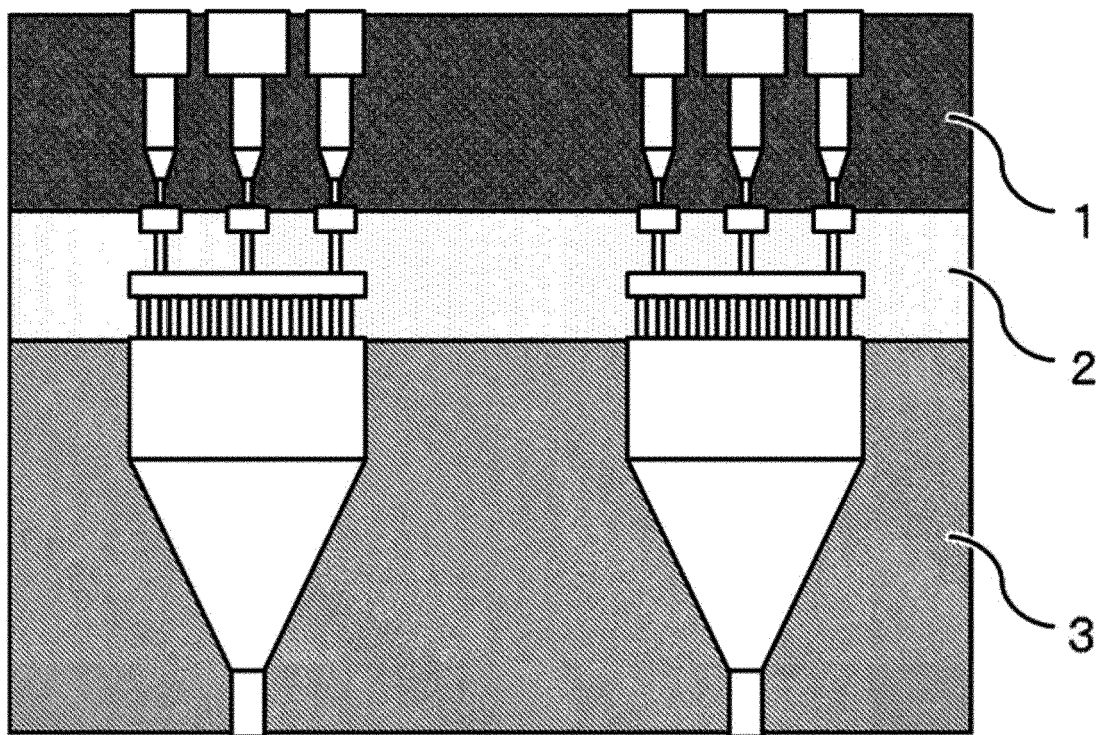


FIG. 12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/029919

A. CLASSIFICATION OF SUBJECT MATTER <i>D01F 8/04</i> (2006.01)i; <i>D02G 3/02</i> (2006.01)i FI: D01F8/04 Z: D02G3/02 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) D01F1/00-9/04; D02G1/00-3/48; D02J1/00-13/00 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Published examined utility model applications of Japan 1922-1996 Published unexamined utility model applications of Japan 1971-2021 Registered utility model specifications of Japan 1996-2021 Published registered utility model applications of Japan 1994-2021 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)																								
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>JP 47-8173 B1 (KANEKAFUCHI BOSEKI KK) 08 March 1972 (1972-03-08) claims, column 5, line 45 to column 6, line 3, fig. 3</td> <td>1-5, 10</td> </tr> <tr> <td>A</td> <td>JP 7-316946 A (UNITIKA LTD.) 05 December 1995 (1995-12-05) claims, fig. 1</td> <td>1-5, 10</td> </tr> <tr> <td>A</td> <td>JP 2006-161263 A (TORAY INDUSTRIES, INC.) 22 June 2006 (2006-06-22) claims, paragraph [0016], fig. 1</td> <td>1-5, 10</td> </tr> <tr> <td>A</td> <td>JP 2019-167646 A (TORAY INDUSTRIES, INC.) 03 October 2019 (2019-10-03) claims, fig. 1</td> <td>1-5, 10</td> </tr> <tr> <td>A</td> <td>WO 2016/002100 A1 (TORAY INDUSTRIES, INC.) 07 January 2016 (2016-01-07) claims, drawings</td> <td>6-10</td> </tr> <tr> <td>A</td> <td>WO 2014/196642 A1 (KANEKA CORP.) 11 December 2014 (2014-12-11) example 1, fig. 9</td> <td>6-10</td> </tr> <tr> <td>A</td> <td>JP 8-325867 A (MITSUBISHI RAYON CO., LTD.) 10 December 1996 (1996-12-10) examples, drawings</td> <td>6-10</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	A	JP 47-8173 B1 (KANEKAFUCHI BOSEKI KK) 08 March 1972 (1972-03-08) claims, column 5, line 45 to column 6, line 3, fig. 3	1-5, 10	A	JP 7-316946 A (UNITIKA LTD.) 05 December 1995 (1995-12-05) claims, fig. 1	1-5, 10	A	JP 2006-161263 A (TORAY INDUSTRIES, INC.) 22 June 2006 (2006-06-22) claims, paragraph [0016], fig. 1	1-5, 10	A	JP 2019-167646 A (TORAY INDUSTRIES, INC.) 03 October 2019 (2019-10-03) claims, fig. 1	1-5, 10	A	WO 2016/002100 A1 (TORAY INDUSTRIES, INC.) 07 January 2016 (2016-01-07) claims, drawings	6-10	A	WO 2014/196642 A1 (KANEKA CORP.) 11 December 2014 (2014-12-11) example 1, fig. 9	6-10	A	JP 8-325867 A (MITSUBISHI RAYON CO., LTD.) 10 December 1996 (1996-12-10) examples, drawings	6-10
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.																								
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family																								
Date of the actual completion of the international search 14 October 2021	Date of mailing of the international search report 26 October 2021																							
Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan	Authorized officer Telephone No.																							

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/029919

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The inventions in claims 1-5 and claim 10 citing claims 1-5, and the inventions in claims 6-9 and claim 10 citing claims 6-9, are not in a technical relationship that involves identical or corresponding special technical features therebetween, and thus the claims include the following two invention groups.

(Invention 1) The inventions in claims 1-5 and claim 10 citing claims 1-5

Invention 1 has the special technical feature of: in a fiber cross section of a composite fiber, two or more types of polymers having different dissolution speeds in a solvent are layered in the direction going from the fiber center to fiber surface, the innermost layer including the fiber center contains an easily soluble polymer, and in at least one layer other than the innermost layer, two types of poorly soluble polymers having different melting points are unevenly distributed; and a hollow fiber being a configuration in which the easily soluble polymer has been removed from the composite fiber.

(Invention 2) The inventions in claims 6-9 and claim 10 citing claims 6-9

Invention 2 has the special technical feature of a multifilament containing a flat hollow fiber, the coefficient of variation CV of the rotation angle of the major axis of the flat hollow fiber being 15-50%.

The inventions in claims 6-9 and claim 10 citing claims 6-9 are not inventions in the same category that includes all matters specifying the invention of claim 1, and are not inventions for which, as a result of examining the claims classified as invention 1, an examination may be made without a substantial need for additional prior art searches and judgement. Furthermore, there is no other circumstance where it is more efficient to examine the inventions in claims 6-9 and claim 10 citing claims 6-9 together with invention 1.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

- Remark on Protest**
- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
 - ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
 - ☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2021/029919

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	47-8173	B1	08 March 1972	(Family: none)	
JP	7-316946	A	05 December 1995	(Family: none)	
JP	2006-161263	A	22 June 2006	(Family: none)	
JP	2019-167646	A	03 October 2019	(Family: none)	
WO	2016/002100	A1	07 January 2016	(Family: none)	
WO	2014/196642	A1	11 December 2014	US 2016/0088888	A1
				example 1, fig. 9	
				US 2018/0343945	A1
				CN 105263348	A
				KR 10-2016-0006260	A
				AP 201508871	A
				ZA 201508567	B
JP	8-325867	A	10 December 1996	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2019167646 A [0008]
- JP 2011208313 A [0114]
- JP 2020137899 A [0194]
- JP 2020194085 A [0194]