(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 579 010 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
02.07.2025 Bulletin 2025/27

(21) Application number: **23857395.0**

(22) Date of filing: **23.08.2023**

(51) International Patent Classification (IPC):
D01F 6/84 *(2006.01)* ***D01F 8/14*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
D01F 6/84; D01F 8/14

(86) International application number:
PCT/JP2023/030391

(87) International publication number:
WO 2024/043287 (29.02.2024 Gazette 2024/09)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **26.08.2022 JP 2022134679**
02.03.2023 JP 2023031721

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(54) SYNTHETIC FIBERS

(57) The present invention provides synthetic fibers that can be suitably employed for a fiber structure. The synthetic fibers demonstrate excellent dye exhaustion in the dyeing step, and thus can achieve deep colors, allows a rapid dyeing, and realizes favorable fiber texture. These synthetic fibers have a loss tangent peak temperature of 100°C to 150°C, a loss tangent peak value of 0.15 or greater, and a dry heat shrinkage rate of 5% or greater but less than 15%.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a synthetic fiber.

BACKGROUND ART

[0002] Synthetic fibers, particularly polyester fibers, have excellent mechanical properties and dimensional stability and are therefore used in a wide range of applications, from clothing applications to non-clothing applications such as materials and medical use.

[0003] As people's lives become more affluent, there is a demand for higher functionality, and the development of fiber products having diverse functions is progressing. At the same time, in light of recent concerns about environmental issues, resource and energy conservation is being required in various industries, and the fiber industry is no exception to this requirement.

[0004] For the resource and energy conservation in the synthetic fibers, efforts are being made to recycle non-product parts during a production process, recycle final products, reduce utility usage throughout the production process, and increase energy efficiency. In the production process, resource and energy conservation is required particularly in a dyeing step in which a lot of water and energy are consumed. Conceivable methods include improving a dye exhaustion ability to enable a high color development property even with a small amount of dye used, or improving energy efficiency in the dyeing step.

[0005] For example, there has been proposed a technique of producing a textile having an excellent color development property while achieving resource and energy conservation by changing a fiber structure before dyeing in the dyeing step for a polyester fiber and thereby exhibiting an excellent dye exhaustion ability.

[0006] That is, Patent Literature 1 discloses that by applying a high-temperature heat treatment using steam or a water-soluble non-swelling medium before dyeing, the fiber structure is changed and a loss tangent (tan δ) determined by dynamic viscoelasticity measurement is controlled, which increases dyeing sites, improves the dye exhaustion ability, and improves dye utilization efficiency.

[0007] In addition, Patent Literature 2 discloses that by focusing on the control of a tan δ peak temperature determined by dynamic viscoelasticity measurement and copolymerizing an aliphatic dicarboxylic acid to produce a modified polyester fiber, dyeability of the polyester fiber at a normal pressure is improved, and the polyester fiber has a high shrinkage property even after a high-temperature treatment, which overcomes high temperature and high pressure conditions required for dyeing a general polyester fiber.

CITATION LIST

PATENT LITERATURE

[0008]

Patent Literature 1: JPH05-279917A
Patent Literature 2: JPH10-204723A

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0009] In the technique in Patent Literature 1, the dye utilization efficiency has been improved, but the obtained fiber structure is loose, so that the shrinkage of the fiber during the high-temperature heat treatment is excessively large, and a textile and the like to which this technique is applied may have excessive denseness between fibers and may have a fiber structure having a hardened texture. In addition, when all steps in the fiber production process are taken into consideration, such as the need to add steps that are not generally performed, excessive energy may be consumed.

[0010] In the technique in Patent Literature 2, the normal pressure dyeability can be obtained by controlling the tan δ peak temperature determined by dynamic viscoelasticity measurement, but it is also a technique aimed at a high shrinkage property, and as a dry heat shrinkage increases, the texture of the textile and the like may be hardened due to the dense structure, similar to the synthetic fiber described in Patent Literature 1.

[0011] In view of the above problems in the related art, an object of the present invention is to provide a synthetic fiber that has an excellent dye exhaustion ability in a dyeing step, that has a fast dyeing speed, and that is suitable for producing a

fiber structure both having a deep dyeing color and a soft texture, which have been difficult to achieve in the related art.

SOLUTION TO PROBLEM

[0012] The above problems can be solved by the following (1) to (3).

(1) A synthetic fiber, having a loss tangent peak temperature of 100°C or higher and 150°C or lower, a loss tangent peak value of 0.15 or more, and a dry heat shrinkage of 5% or more and less than 15%.
(2) The synthetic fiber according to (1), having a loss tangent area from 30°C to 130°C of 4.0°C or more and 7.5°C or less.
(3) The synthetic fiber according to claim (1) or (2), in which when a fiber cross section after dyeing to have an L* value of 20 or less is displayed as a 256-level grayscale image, an absolute value of a difference between an average pixel value of a circle that is concentric with a center of an inscribed circle and that has an area of 10% of an area of the fiber cross section and an average pixel value of an outer peripheral portion that has an area of 10% of the area of the fiber cross section is 15 or less.

ADVANTAGEOUS EFFECTS OF INVENTION

[0013] The synthetic fiber according to the present invention can produce a deep color in the dyeing step because of excellent dye exhaustion ability, has a fast dyeing speed, and can produce a fiber structure that maintains a soft texture even after dyeing.

DESCRIPTION OF EMBODIMENTS

[0014] A synthetic fiber according to the present invention has a loss tangent peak temperature of 100°C or higher and 150°C or lower, a loss tangent peak value of 0.15 or more, and a dry heat shrinkage of 5% or more and less than 15%.

[0015] The synthetic fiber in the present invention refers to a fiber produced by chemical synthesis, such as a polyester fiber, a polyamide fiber, and an acrylic fiber. The synthetic fiber in the present invention is preferably a polyester fiber, which can easily introduce a copolymerization component in a production process and can be dyed with a disperse dye in an amorphous portion. Further, the polyester fiber preferred in the present invention includes terephthalic acid and ethylene glycol as main components, and may include a copolymerization component. The copolymerization component may be used alone or in combination of two or more thereof.

[0016] The synthetic fiber according to the present invention needs to have a loss tangent peak temperature of 100°C or higher and 150°C or lower.

[0017] The loss tangent referred to here is also referred to as a loss factor or tan δ, is a ratio of a loss modulus and a storage modulus determined by dynamic viscoelasticity measurement, and represents a magnitude of a micro Brownian motion of an amorphous portion in a fiber structure.

[0018] The loss tangent peak temperature in the present invention refers to a value determined as a loss tangent peak temperature when the loss tangent (dimensionless quantity) is measured using a dynamic viscoelasticity measuring device, under conditions of clamping the synthetic fiber at a distance between chucks of 30 mm, applying a tension of 0.15 g/dtex, and increasing the temperature from 30°C to 200°C at a temperature increase rate of 3°C/min and a frequency of 110 Hz. Examples of the dynamic viscoelasticity measuring device include "RHEOVIBRON DOV-II-EP" manufactured by ORIENTEC CO., LTD.

[0019] When the loss tangent peak temperature is 100°C or higher, in a dyeing step, the micro Brownian motion of the amorphous portion is sufficiently large, dyeability of the amorphous portion with a disperse dye is improved and thus a dye exhaustion ability is excellent to thereby make it possible to produce a deep color, a dyeing speed is fast, and shrinkage in a heat treatment is prevented, resulting in an excellent texture.

[0020] On the other hand, when the loss tangent peak temperature is higher than 150°C, in the dyeing step, the micro Brownian motion of the amorphous portion is small, the dyeability of the amorphous portion with a disperse dye is low and thus the dye exhaustion ability is low, making it difficult to obtain a deep color and resulting in insufficient dyeing. When the loss tangent peak temperature is 150°C or lower, in the dyeing step, the dye exhaustion ability is excellent to thereby make it possible to produce a deep color and have an excellent color development property.

[0021] The loss tangent peak temperature is preferably 110°C or higher, more preferably 120°C or higher, and is preferably 140°C or lower.

[0022] The synthetic fiber according to the present invention needs to have a loss tangent peak value of 0.15 or more.

[0023] When the loss tangent peak value is 0.15 or more, in the dyeing step, the micro Brownian motion is large, the dyeability of the amorphous portion with a disperse dye is improved and thus the dye exhaustion ability is excellent to thereby make it possible to produce a deep color, the dyeing speed is fast, and the color development property is excellent.

[0024] The loss tangent peak value is preferably 0.20 or less, and more preferably in the range of 0.15 to 0.20, from the viewpoint of preventing an increase in dry heat shrinkage.

[0025] The loss tangent peak value can be measured by the above method using a dynamic viscoelasticity measuring device.

[0026] The synthetic fiber according to the present invention preferably has a loss tangent area from 30°C to 130°C of 4.0°C or more and 7.5°C or less when a relationship between a temperature and the loss tangent is graphed.

[0027] The loss tangent area from 30°C to 130°C is an area obtained by measuring the loss tangent using a dynamic viscoelasticity measuring device, under conditions of clamping the synthetic fiber at a distance between chucks of 30 mm, applying a tension of 0.15 g/dtex, and increasing the temperature from 30°C to 130°C at a temperature increase rate of 3°C/min and a frequency of 110 Hz, performing plotting with the horizontal axis being the temperature (°C) and the vertical axis being the loss tangent (dimensionless quantity), dividing the horizontal axis into sections every 1°C, and integrating the graph.

[0028] The loss tangent area from 30°C to 130°C represents a cumulative magnitude of the micro Brownian motion of the amorphous portion of the fiber structure in the synthetic fiber dyeing step. The larger the value, the more active the micro Brownian motion is in the dyeing step, improving the dye exhaustion ability and making it possible to produce a deep color.

[0029] The loss tangent area from 30°C to 130°C is preferably 4.0°C or more since, in the dyeing step, the micro Brownian motion is sufficiently large, the dyeability of the amorphous portion with a disperse dye is improved and thus the dye exhaustion ability is improved to thereby make it possible to produce a deep color, the color development property is excellent, the dyeing speed is fast, and the color development property is excellent. On the other hand, when the loss tangent area is larger than 7.5°C, the micro Brownian motion is large, the dyeability of the amorphous portion with a disperse dye is further improved and thus the dye exhaustion ability is improved, and the color development property is improved; however, the shrinkage property of the amorphous portion also increases, causing a large dimensional change and hardening of the texture. Therefore, the loss tangent area is preferably 7.5°C or less.

[0030] The loss tangent area from 30°C to 130°C is more preferably 4.2°C or more, still more preferably 4.5°C or more, and is more preferably 7.0°C or less.

[0031] The synthetic fiber according to the present invention needs to have a dry heat shrinkage of 5% or more and less than 15%.

[0032] When the dry heat shrinkage is 5% or more, in case of dyeing with a disperse dye, there are sufficient amorphous portions into which the dye can be introduced, and the color development property is excellent. On the other hand, when the dry heat shrinkage is less than 15%, in a heat treatment, the synthetic fiber does not shrink excessively and does not harden or deteriorate in texture.

[0033] The dry heat shrinkage is preferably 14% or less.

[0034] The dry heat shrinkage is calculated based on a length L0 and a length L1 according to the following equation, the length L0 being a length when a load of 0.03 cN/dtex is applied after preparing a hank (10 turns) of the synthetic fiber using a sizing reel at a speed of 1 m/turn in an environment with a temperature of 20°C and a humidity of 65% RH and leaving the hank to stand for 24 hours in an environment with a temperature of 20°C and a humidity of 65% RH, and the length L1 being a length when a load of 0.03 cN/dtex is applied after a hank prepared as above is subjected to a heat treatment at 160°C for 5 minutes without a load, and is then left to stand for 24 hours in an environment with a temperature of 20°C and a humidity of 65% RH.

$$\text{Dry heat shrinkage (\%)} = \{(L0-L1)/L0\} \times 100$$

[0035] Further, in the synthetic fiber according to the present invention, when a fiber cross section after dyeing to have an L* value of 20 or less is displayed as a 256-level grayscale image, an absolute value of a difference between an average pixel value of a circle that is concentric with a center of an inscribed circle and that has an area of 10% of an area of the fiber cross section and an average pixel value of an outer peripheral portion that has an area of 10% of the area of the fiber cross section is preferably 15 or less, which is sufficient to determine whether a dye has penetrated the fiber cross section. Note that, the L* value represents lightness in the L*a*b* color space, and is measured using a spectrophotometer with a D65 light source, a viewing angle of 10°, and optical conditions of SCE (specular component exclude method).

[0036] When the absolute value of the difference between the average pixel values is 15 or less, the dye penetrates the fiber, and unlike the case where only the surface of the fiber is dyed, the dye is evenly absorbed into the amorphous portion of the entire fiber, and therefore, the dye exhaustion ability is improved to make it possible to produce a deep color, and the color development property is excellent, which is preferable.

[0037] The absolute value of the difference is more preferably 10 or less, and when the dye has uniformly penetrated the fiber, the absolute value of the difference is 0, so that there is no particular lower limit value.

[0038] Next, a form of the synthetic fiber according to the present invention will be described.

[0039] The synthetic fiber according to the present invention is not particularly limited with respect to the form of the fiber, and may be in any form such as a monofilament, a multifilament, or a staple, and in order to take advantage of the property of an excellent dye exhaustion ability, the synthetic fiber is preferably in the form of a multifilament or a staple.

[0040] A single fiber fineness and the number of filaments of the synthetic fiber according to the present invention are suitably selected appropriately depending on applications and required properties, and assuming a practical range, the fineness as a multifilament is preferably 10 dtex to 3000 dtex.

[0041] The fineness (dtex) in the present invention is calculated by measuring a weight of 100 m of hank-reeled fiber using an electric sizing reel in an environment with a temperature of 20°C and a humidity of 65% RH, and using the following equation.

$$\text{Fineness (dtex)} = \text{weight (g) of 100 m of fiber} \times 100$$

[0042] The synthetic fiber preferably has a fineness of 10 dtex or more since it is less likely to break yarn and has good process passability, and it generates less fluff during use and has excellent durability. On the other hand, the synthetic fiber preferably has a fineness of 3000 dtex or less since flexibility of the fiber and the fiber structure is not impaired.

[0043] An elongation of the synthetic fiber according to the present invention can be adjusted according to the applications and the required properties by a production method to be described later. Here, the elongation in the present invention is calculated in accordance with 8.5.1 in JIS L1013:2010 (Testing methods for man-made filament yarns). Specifically, the elongation (%) is calculated by performing a tensile test under conditions of an environment with a temperature of 20°C and a humidity of 65% RH, an initial sample length of 20 cm, and a tensile speed of 20 cm/min, dividing a stress (cN) at a point showing the maximum load by the fineness (dtex) to calculate a strength (cN/dtex), and using an elongation (L1) at the point showing the maximum load and the initial sample length (L0) according to the following equation.

$$\text{Elongation (\%)} = \{(L1-L0)/L0\} \times 100$$

[0044] The larger the elongation, the more likely the fiber is stretched and deformed and does not break even when subjected to sudden deformation. However, the stretching deformation during molding processing may cause the properties of the fiber product to be unstable. Therefore, in consideration of handleability of the fiber, the elongation of the synthetic fiber according to the present invention is more preferably 30% to 60%. In particular, an elongation of 60% or less is suitable since the dimensional stability of the fiber and the fiber structure is improved.

[0045] In addition, the elongation of the synthetic fiber according to the present invention may be adjusted according to the required elongation for use. It is particularly preferable that the elongation be adjusted to 30% to 50% when used for clothing applications, and 20% to 40% when used for non-clothing applications.

[0046] A cross-sectional shape of the synthetic fiber according to the present invention is not particularly limited and may be appropriately selected depending on the applications and the required properties. The cross-sectional shape may be a perfect circle or a non-circle.

[0047] Specific examples of the non-circular cross section include multi-lobed, polygonal, flat, elliptical, C-shaped, H-shaped, S-shaped, T-shaped, W-shaped, X-shaped, Y-shaped, square, parallel-cross shaped, and hollow cross sections, but are not limited thereto. In order to effectively utilize the deep dyeing property of the synthetic fibers according to the present invention to produce a textile having a higher quality, it is suitable to prevent glare, which is a property of the synthetic fiber that reflects light from a certain angle with high intensity. From this viewpoint, it is preferable to form the synthetic fiber in a complex cross-sectional shape such as a multi-lobe shape, H-shape, S-shape, T-shape, W-shape, X-shape, Y-shape, square shape, or parallel cross shape. With such a cross-sectional shape, when the synthetic fiber is made into a textile, there is no flat surface on the surface, and light reflection is dispersed, making the effect of the deep dyeing of the present invention more pronounced.

[0048] The synthetic fiber according to the present invention can be processed into false twisted yarns or twisted yarns in the same manner as general fibers, and can also be woven and knitted in the same manner as general fibers.

[0049] The fiber structure made of the synthetic fiber according to the present invention can have various forms by utilizing known methods. Specific examples thereof include woven fabrics, knitted fabrics, pile fabrics, nonwoven fabrics, spun yarns, and wadding. In addition, in these fiber structures, various weaving or knitting structures can be used depending on the applications, and plain weave, twill weave, satin weave, or variations of these, warp knitting, weft knitting, circular knitting, lace knitting, or variations of these, and the like can be suitably used. Needless to say, the synthetic fiber according to the present invention may be combined with other fibers by interweaving or interknitting when being made into a fiber structure, or may be made into a mixed yarn with other fibers and then into a fiber structure.

[0050] Next, a method for producing the synthetic fiber according to the present invention will be described below.

[0051] The synthetic fiber according to the present invention can be produced by known methods such as a melt

spinning method, a drawing method, and a false twisting method.

[0052] In the present invention, since it is preferable to adjust a moisture content in a raw material to 0.3 wt% or less before melt spinning, it is preferable to dry the raw material as necessary. The moisture content in the raw material is preferably 0.3 wt% or less since no foaming occurs due to moisture during the melt spinning, and the spinning can be stably performed. It is also preferred since, depending on the type of the raw material, a decrease in mechanical properties and deterioration in color tone due to hydrolysis can be prevented. The moisture content in the raw material is more preferably 0.1 wt% or less.

[0053] In the case of melt spinning the synthetic fiber, examples of a method for discharging the material from a spinneret to form a fiber thread include the following examples, but are not limited thereto. As a first example, a chip, which has a composition same as a composition of a final fiber, is optionally dried and then fed into a melt spinning machine, melted, and measured by using a measuring pump. Thereafter, the resultant is introduced into a heated spinning pack in a spinning block, the molten polymer is filtered in the spinning pack, and then the product is discharged from a spinneret to form a fiber thread. As a second example, chips having different compositions are optionally dried and then mixed in a chip state so as to obtain a final fiber composition, and then the mixed chips are fed to a melt spinning machine, melted, and measured by using a measuring pump. Thereafter, the resultant is introduced into a heated spinning pack in a spinning block, sea-island components of the molten polymer are kneaded and filtered in the spinning pack, and then the product is discharged from a spinneret to form a fiber thread. As a third example, chips having different compositions are optionally dried, and then the chips are fed separately, melted and measured by using a measuring pump. Thereafter, the resultant is introduced into a heated spinning pack in a spinning block, the molten polymer is kneaded so as to have a final fiber composition and filtered in the spinning pack, and then the product is discharged from a spinneret to form a fiber thread.

[0054] The fiber thread discharged from the spinneret is cooled and solidified by using a cooling device, taken off by a first godet roller, passes through a second godet roller, and wound by a winder to form a wound yarn. In addition, an oil supplying device may be used to supply oil to the fiber thread, and an entanglement device may be used to entangle the fiber thread.

[0055] A spinning temperature in the melt spinning can be appropriately selected depending on melting points and heat resistance of the components in the fiber, and is preferably 240°C to 300°C. The spinning temperature is preferably 240°C or higher since an elongational viscosity of the fiber thread discharged from the spinneret is sufficiently reduced to enable stable discharge, a spinning tension is not excessively high, and yarn breakage is prevented. On the other hand, the spinning temperature is preferably 300°C or lower since thermal decomposition during spinning can be prevented, and a decrease in mechanical properties and coloring of the synthetic fiber to be obtained can be prevented.

[0056] A spinning speed in the melt spinning can be appropriately selected depending on a composite ratio of the components in the fiber, the spinning temperature, or the like, and in the case of a two-step method, it is preferably 1000 m/min to 3000 m/min. When the spinning speed in the case of the two-step method is 1000 m/min or more, the running thread is stable and yarn breakage can be prevented, which is preferable. On the other hand, when the spinning speed in the case of the two-step method is 3000 m/min or less, yarn breakage can be eliminated by controlling the spinning tension and the spinning can be stably performed, which is preferable. In the case of a one-step method in which spinning and drawing are performed simultaneously without winding the fiber, the spinning speed is preferably 1000 m/min to 3000 m/min for a low-speed roller and 2500 m/min to 6000 m/min for a high-speed roller. The low-speed roller and the high-speed roller preferably have the spinning speed within the above ranges since the running thread is stabilized, yarn breakage can be prevented, and the spinning can be stably performed.

[0057] In order to make the synthetic fiber have a loss tangent peak temperature of 100°C or higher and 150°C or lower, a loss tangent peak value of 0.15 or more, and a dry heat shrinkage of 5% or more and less than 15%, it is preferable to perform drawing or false twisting by using a one-step method or a two-step method, and the drawing during the process may be either a one-stage drawing method or a multi-stage drawing method having two or more stages. A heating method in the drawing or the false twisting is not particularly limited as long as the device can directly or indirectly heat the running thread.

[0058] A drawing temperature in the case of performing drawing can be appropriately selected depending on glass transition temperatures and melting points of the components in the fiber, the strength and the elongation of the fiber after drawing, or the like, and is preferably 60°C to 120°C. The drawing temperature is preferably 60°C or higher since the thread to be drawn is sufficiently preheated, the thermal deformation during drawing is uniform, the occurrence of fineness unevenness is prevented, and a high-quality fiber having excellent uniformity in a fiber longitudinal direction can be obtained. On the other hand, the drawing temperature is preferably 120°C or lower since the fusion of fibers and thermal decomposition caused by contact with the heated rollers can be prevented, and the process passability and the quality are good. It is also preferred since sliding properties of the fiber against a drawing roller is improved, yarn breakage is prevented, and the drawing can be performed stably.

[0059] A drawing ratio in the case of performing drawing can be appropriately selected depending on the elongation of the fiber before drawing and the strength and the elongation of the fiber after drawing, and is preferably 1.02 times to 5.0 times. When the drawing ratio is 1.02 times or more, the drawing can improve the mechanical properties of the fiber, such

as the strength and the elongation, which is preferable. On the other hand, when the drawing ratio is preferably 5.0 times or less, yarn breakage during drawing is prevented and the drawing can be performed stably, which is preferable. Specifically, in order to have practical utility and to have a loss tangent peak value of 0.15 or more, a drawing ratio that results in an elongation after drawing of about 40% is preferred.

[0060] A drawing speed in the case of performing drawing can be appropriately selected depending on whether the drawing method is a one-step method or a two-step method. In the case of a one-step method, the speed of the high-speed roller at the above spinning speed corresponds to the drawing speed. In the case of performing drawing by using a two-step method, the drawing speed is preferably 100 m/min to 1000 m/min. In the case of a two-step method, when the drawing speed is preferably 100 m/min or more, the running thread is stable and yarn breakage can be prevented, which is preferable. When the drawing speed is 1000 m/min or less, yarn breakage during drawing is prevented and the drawing can be performed stably, which is preferable.

[0061] It is also preferable to perform heat setting at 100°C to 150°C. The heat setting is a treatment in which the synthetic fiber after drawing is subjected to a heat treatment to stabilize the dimension. The heat setting is preferably performed at 100°C or higher since the heat setting sufficiently crystallizes the fiber, the loss tangent peak temperature is 100°C or higher, and the dry heat shrinkage is less than 15%, and thus a change in physical properties or texture caused by shrinkage due to the heat treatment can be prevented. On the other hand, the heat setting temperature is preferably 150°C or lower since the loss tangent peak temperature is 150°C or lower, the dry heat shrinkage is 5% or more, and the process passability and the quality are good.

[0062] In the case of performing false twisting, the elongation of the undrawn yarn or drawn yarn used can be appropriately selected depending on the applications and the required properties, and is preferably in a range of 30% to 300%. When the elongation is 30% or more, the fluff of the false twisted yarn made of the synthetic fiber and yarn breakage during the false twisting can be prevented, and when the elongation is 300% or less, the false twisting can be performed stably.

[0063] Examples of a device used for the false twisting include those shown below, but are not limited thereto. As a first example, a false twisting device including a 1DR (1 draw roller), a 1HT (1 heater), a cooling plate, a false twister, 2DR (2 draw roller), 3DR (3 draw roller), 4DR (4 draw roller), and a winder is used. A processing ratio between the 1DR and the 2DR can be selected depending on the elongation of the fiber used in the processing and the elongation of the false twisted yarn made of the synthetic fiber, and is preferably in a range of 1.1 times to 3.0 times. The heater may be of either contact or non-contact type. A 1HT temperature can be appropriately selected depending on the glass transition temperatures and melting points of the components of the synthetic fiber, and the strength, the elongation, the dry heat shrinkage, and a crimp recovery rate of the fiber after the false twisting. The upper limit of the 1HT temperature may be any temperature at which the undrawn yarn or drawn yarn used does not fuse in the heater. The false twister is preferably of a friction false twist type, and examples thereof include a friction disk type and a belt nip type. Preferably, it is of a friction disk type. The ratios between the 2DR and the 3DR and between the 3DR and the 4DR can be appropriately set depending on the false twisted yarn made of the synthetic fiber, and are generally preferably 0.9 to 1.0. In order to improve the process passability of the false twisted yarn, entanglement may be imparted by an entanglement nozzle or additional oil may be applied by using an oil supplying guide between the 2DR and the 3DR, between the 3DR and the 4DR, or between the 4DR and the winder.

[0064] As a second example, a false twisting device including a 1DR, a 1HT, a cooling plate, a false twister, 2DR, 3DR, 2HT (2 heater), 4DR, and a winder is used. A processing ratio between the 1DR and the 2DR can be selected depending on the elongation of the fiber used in the processing and the elongation of the false twisted yarn made of the synthetic fiber, and is preferably in a range of 1.1 times to 3.0 times. The 1HT temperature can be appropriately selected depending on the glass transition temperatures and melting points of the components of the synthetic fiber, and the strength, the elongation, the dry heat shrinkage, and the crimp recovery rate of the fiber after the false twisting. The upper limit of the 1HT temperature may be any temperature at which the undrawn yarn or drawn yarn used does not fuse in the heater. The false twister is preferably of a friction false twist type, and examples thereof include a friction disk type and a belt nip type. Preferably, it is of a friction disk type. In order to improve the process passability of the false twisted yarn, entanglement may be imparted by an entanglement nozzle between the 2DR and the 3DR. A processing ratio between the 3DR and the 4DR can be selected depending on the elongation of the fiber used in the processing and the elongation of the false twisted yarn made of the synthetic fiber, and is preferably in a range of 0.8 times to 1.1 times. A 2HT temperature can be appropriately selected depending on the glass transition temperatures and melting points of the components of the synthetic fiber, and the strength, the elongation, the dry heat shrinkage, and the crimp recovery rate of the fiber after the false twisting. The upper limit of the 2HT temperature may be any temperature at which the undrawn yarn or drawn yarn used does not fuse in the heater. Additional oil may be applied by using an oil supplying guide between the 4DR and the winder.

EXAMPLES

[0065] Hereinafter, the present invention will be described in more detail with reference to Examples. Note that, the property values in Examples were determined by the following methods.

A. Melt Viscosity

[0066] A chip-like polymer sample was prepared by reducing the moisture content to 200 ppm or less using a vacuum dryer, and the measurement was performed using a Capilograph 1B manufactured by Toyo Seiki Seisaku-sho, Ltd. The time from when the sample was charged into a heating furnace to when the measurement was started was 5 minutes, and the melt viscosity was measured at a measurement temperature of 290°C while changing a strain rate stepwise in a nitrogen atmosphere. Note that, in Examples and Comparative Examples, a melt viscosity of 1216 s^{-1} was recorded.

B. Fineness

[0067] In an environment with a temperature of 20°C and a humidity of 65% RH, 100 m of the fiber obtained in each of Examples and Comparative Examples was hank-reeled off using an electric sizing reel manufactured by INTEC Inc. The weight of the obtained hank was measured, and the fineness (dtex) was calculated using the following equation.

$$\text{Fineness (dtex)} = \text{weight (g) of 100 m of fiber} \times 100$$

[0068] Note that, the measurement was performed five times for one sample, and an average value thereof was defined as the fineness.

C. Strength and Elongation

[0069] The strength and the elongation were calculated in accordance with 8.5.1 in JIS L1013:2010 (Testing methods for man-made filament yarns) using the fiber obtained in each of Examples and Comparative Examples as a sample. A tensile test was performed using a TENSILON UTM-III-100 manufactured by ORIENTEC CO., LTD. under conditions of an initial sample length of 20 cm and a tensile speed of 20 cm/min under an environment with a temperature of 20°C and a humidity of 65% RH. The stress (cN) at the point showing the maximum load was divided by the fineness (dtex) to calculate the strength (cN/dtex), and the elongation (%) was calculated according to the following equation using the elongation (L1) at the point showing the maximum load and the initial sample length (L0).

$$\text{Elongation (\%)} = \{(L1\text{-}L0)/L0\} \times 100$$

[0070] Note that, the measurement was performed ten times for one sample, and an average value thereof was defined as the strength and the elongation.

D. Dry Heat Shrinkage

[0071] In an environment with a temperature of 20°C and a humidity of 65% RH, a hank (10 turns) of the fiber obtained in each of Examples and Comparative Examples was prepared using a sizing reel at 1 m/turn, followed by leaving to stand for 24 hours. Thereafter, under the above environment, a load of 0.03 cN/dtex was applied to the hank, and the sample length L0 was measured. Next, the hank was subjected to a heat treatment in an oven at 160°C for 5 minutes without a load, and then left to stand for 24 hours in an environment with a temperature of 20°C and a humidity of 65% RH. Thereafter, a load of 0.03 cN/dtex was applied to the hank, and the sample length L1 was measured. The dry heat shrinkage (%) was calculated according to the following equation using the sample lengths L0 and L1 before and after the treatment in the oven.

$$\text{Dry heat shrinkage (\%)} = \{(L0\text{-}L1)/L0\} \times 100$$

[0072] Note that, the measurement was performed three times for one sample, and an average value thereof was defined as the dry heat shrinkage.

E. Melting Point (Tm) and Heat Amount of Fusion (ΔHm)

[0073] The fiber obtained in each of Examples and Comparative Examples was used as a sample, and was subjected to DSC measurement using a differential scanning calorimeter (DSC) Model Q2000 manufactured by TA Instruments Japan Inc., with the temperature being increased from 30°C to 280°C at a temperature increase rate of 16°C/min, and the melting point (Tm) and the heat amount of fusion (ΔHm) were calculated from a melting peak observed during the temperature increase process. The measurement was performed three times for one sample, and an average value thereof was

defined as the heat amount of fusion. Note that, when a plurality of melting peaks were observed, Tm and ΔHm were read in order from the melting peak top on the lowest temperature side and recorded separately.

F. Loss Tangent Peak Temperature, Peak Value, and Area

[0074] The fiber obtained in each of Examples and Comparative Examples was used as a sample, and dynamic viscoelasticity measurement was performed using RHEOVIBRON DOV-II-EP manufactured by ORIENTEC CO., LTD. The measurement was performed under conditions of clamping the sample at a distance between chucks of 30 mm, applying a tension of 0.15 g/dtex, and increasing the temperature from 30°C to 200°C at a temperature increase rate of 3°C/min and a frequency of 110 Hz. Plotting was performed with the horizontal axis being the temperature (°C) and the vertical axis being the loss tangent, and the loss tangent peak temperature, the loss tangent peak value, and the loss tangent area from 30°C to 130°C were evaluated.

G. L* Value

[0075] The fiber obtained in each of Examples and Comparative Examples was used as a sample, and about 5 g of cylindrical knitted fabric was prepared using a circular knitting machine NCR-BL (tank diameter: 3.5 inches (8.9 cm), 27 gauge) manufactured by EIKO INDUSTRIAL CO,. LTD, was then refined for 20 minutes at 80°C in an aqueous solution containing 1 g/L sodium carbonate and 1 g/L of a surfactant GRAN UP US-20 manufactured by Meisei Chemical Works, Ltd., and was then rinsed with running water for 5 minutes and dried for 30 minutes in a hot air dryer at 60°C. After being refined, the cylindrical knitted fabric was dyed in a dye solution in which 3.0 wt% of Dianix Navy S-2G 200% manufactured by DyStar as a disperse dye was added so that a pH was adjusted to 5.0, at a bath ratio of 1:50 at 130°C for a predetermined time (5 minutes, 15 minutes, 30 minutes), and then rinsed with running water for 5 minutes. The dyed cylindrical knitted fabric was reduced and washed in an aqueous solution containing 0.7 g/L sodium hydroxide and 2 g/L sodium dithionite at a bath ratio of 1:50 at 80°C for 20 minutes, and then rinsed with running water for 5 minutes and dried for 30 minutes in a hot air dryer at 60°C. Thereafter, finish setting was performed at 160°C for 1 minute. The cylindrical knitted fabric after the finish setting was used as a sample, and the L* value was measured using a spectrophotometer CM-3700d manufactured by Konica Minolta Japan, Inc., with a D65 light source, a viewing angle of 10°, and optical conditions of SCE (specular component exclude method). Note that, the measurement was performed three times for one sample, and an average value thereof was defined as the L* value.

H. Pixel Value after Dyeing

[0076] The cylindrical knitted fabric prepared in the above G, which had been dyed for 30 minutes and then subjected to finish setting, was used as a sample. The fiber in the cylindrical knitted fabric was cut perpendicular to a fiber axis direction at an any position in the fiber axis direction, and a micrograph of the cut surface was captured at a magnification of 2000 times using an optical microscope manufactured by Olympus Corporation, with a white background having a pixel value of 200 to 230 after conversion to a grayscale image to be described later. The micrograph was converted into a 256-level grayscale image using image processing software (WINROOF, manufactured by MITANI CORPORATION), and then, for 10 fiber cross sections randomly extracted from the same photograph, an average pixel value of a circle that was concentric with a center of an inscribed circle of the fiber cross section and that had an area of 10% of an area of the fiber cross section was calculated, the average value was defined as a central pixel value, an average pixel value of an outer peripheral portion that had an area of 10% of the area of the fiber cross section was calculated, and the average value was defined as an outer peripheral pixel value.

I. Texture

[0077] The cylindrical knitted fabric after finish setting prepared in the above G was evaluated on the following four criteria by a panel of five inspectors with five years or more of experience in determining quality, and the average of the results given by the five inspectors was regarded as the texture evaluation result of the fabric. Ratings S, A and B represent pass, while the rating C represents failed.

(Evaluation Criteria)

[0078]

S: it has an excellent texture.
A: it has a good texture.

B: it has a texture.
C: it has a poor texture.

J. Friction Fastness (Staining)

[0079] The evaluation on the friction fastness was performed in accordance with the drying test in 9.2 Friction tester type II (Gakushin type) method of JIS L0849:2013 (Test methods for color fastness to rubbing). The cylindrical knitted fabric after finish setting prepared in the above G was used as a sample, a Gakushin type friction tester RT-200 manufactured by DAIEI KAGAKU SEIKI MFG. co., ltd. was used to rub the sample with white cotton cloth (cotton No. 3-1) specified in JIS L0803:2011, and then a degree of staining of the white cotton cloth was graded using the staining gray scale specified in JIS L0805:2005 to evaluate the friction fastness (staining).

K. Crimp Recovery Rate (CR)

[0080] The evaluation on the crimp recovery rate (CR) was performed in accordance with 6 (sample collection and preparation) and 8.12 (crimp recovery rate) in JIS L1013 (2010). The false twisted yarn was wound into a hank having a hank length of 40 cm and having 10 turns while applying a load of 0.176 mN × fineness (dtex) × 10, and then this hank was subjected to an initial load of 0.176 mN × 20 × fineness (dtex) × 10, subjected to a hot water treatment in 90°C hot water for 20 minutes, dehydrated through filter paper, and then naturally dried for 12 hours or longer. Thereafter, while still applying the above initial load, the false twisted yarn was submerged in water at 20°C (within a range of 18°C to 22°C), followed by applying an additional standard load of 8.82 mN × 20 × fineness (dtex) × 10, and left for 2 minutes, and then the length of the hank after being left was measured and defined as a hank length a. Thereafter, the standard load was removed from the water and the sample was left for 2 minutes with only the initial load applied. The length of the hank after being left was measured and defined as a hank length b. The hank length a and the hank length b were measured five times by changing the sample, and the crimp recovery rate (CR) was calculated according to the following equation and the average value was taken.

Crimp recovery rate (CR) (%) = {(hank length a - hank length b)/hank length a} × 100

(Example 1)

[0081] Polyethylene terephthalate (melt viscosity: 112 Pa s) obtained by copolymerization of 7.0 mol% of isophthalic acid and 4.0 mol% of 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane was used as a chip A, polyethylene terephthalate (melt viscosity: 120 Pa·s) was used as a chip B, and the chip A and the chip B were mixed in advance in a chip form at a blending ratio of 25 wt% of chip A and 75 wt% of chip B respectively such that the final composition was 1.8 mol% of isophthalic acid and 1.0 mol% of 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane regarding a copolymerization amount. The mixed chips were supplied to an extruder-type melt spinning machine, melt-mixed, and discharged from a spinneret (discharge hole diameter: 0.23 mm, discharge hole length: 0.30 mm, number of holes: 36, round holes) at a spinning temperature of 290°C and a discharge rate of 42.0 g/min to obtain a spun thread. The spun thread was cooled with cooling air at a temperature of 20°C and a speed of 25 m/min, supplied with oil from an oil supplying device, bundled, taken off by a first godet roller rotating at 2500 m/min, passed through a second godet roller rotating at the same speed as the first godet roller, and wound by a winder to obtain an undrawn yarn having 168 dtex-36f. The obtained undrawn yarn was drawn between a first hot roller set to 90°C and a second hot roller set to 130°C at a drawing ratio of 2.0 times, and then subjected to heat setting to obtain a drawn yarn having 84 dtex-36f.

[0082] The evaluation results of the fiber properties and the fabric properties of the obtained drawn yarn are shown in Table 1. The obtained drawn yarn had a dry heat shrinkage of 10.4% and had an excellent texture even when finish setting was performed after dyeing. In addition, it can be seen that the loss tangent peak value was large, the loss tangent area was large, and the dyeing speed was so fast that the yarn was sufficiently dyed after 5 minutes of dyeing. Further, a difference in pixel value after dyeing between the inner and outer layers was 3.1, and the dyeing was achieved up to the center, indicating that the dye had been sufficiently exhausted and that the color development property was excellent.

(Examples 2 to 4 and Comparative Examples 1 and 2)

[0083] Drawn yarns were prepared in the same manner as in Example 1, except that proportions of the copolymerization components in the polyethylene terephthalate composition were changed as shown in Table 1 (adjusted by the blending ratio of the chip A and the chip B).

[0084] The evaluation results of the fiber properties and the fabric properties of the obtained drawn yarns are shown in Table 1. As seen from these results, the larger the loss tangent peak value and the larger the loss tangent area, the deeper

the color. On the other hand, in Comparative Example 1, the loss tangent peak value was small, the dyeing was not sufficiently performed unless the dyeing time was 30 minutes, the difference in pixel value after dyeing between the inner and outer layers was large, and the color development property was poor. In Comparative Example 2, the loss tangent peak value and area were excellent and the color development property was good, but the dry heat shrinkage was large, and the texture was poor when finish setting was performed after dyeing. In addition, the friction fastness (staining) was also poor.

(Examples 5 and 6)

[0085] Drawn yarns were prepared in the same manner as in Example 1, except that the temperature of the second hot roller during the drawing was changed as shown in Table 1.

[0086] The evaluation results of the fiber properties and the fabric properties of the obtained drawn yarns are shown in Table 1. It can be seen that when the temperature of the second hot roller during the drawing was lowered, the loss tangent peak value was large, the loss tangent area was large, and the color development property was improved.

(Example 7)

[0087] A drawn yarn was prepared in the same manner as in Example 3, except that the chip A and the chip B were supplied to separate extruders, melted, and then discharged via a conjugate spinning machine from a core-sheath type conjugate spinneret (discharge hole diameter: 0.30 mm, discharge hole length: 0.50 mm, number of holes: 36, round holes), and a conjugate ratio of a core component and a sheath component was as shown in Table 2. Note that, the chip A was used as the sheath component, and the chip B was used as the core component.

[0088] The evaluation results of the fiber properties and the fabric properties of the obtained drawn yarn are shown in Table 2. Due to the core-sheath structure, the dyeing was not sufficiently performed unless the dyeing time was 30 minutes, and the difference in pixel value after dyeing between the inner and outer layers was large, but the loss tangent peak value was large and the loss tangent area was large, so that the color development property was good after dyeing for 30 minutes. As seen from comparison with Example 1 in which the chips were mixed in advance to form a single structure, since polyethylene terephthalate obtained by copolymerization of 7.0 mol% of isophthalic acid and 4.0 mol% of 2,2-bis [4-(2-hydroxyethoxy)phenyl]propane as a sheath component was unevenly distributed on the surface, the friction fastness (staining) was poorer than that of the single structure.

(Example 8 and Comparative Examples 3 and 4)

[0089] Drawn yarns were prepared in the same manner as in Example 7, except that the composite ratio was changed as shown in Table 2.

[0090] The evaluation results of the fiber properties and the fabric properties of the obtained drawn yarns are shown in Table 2. As seen from these results, even in the case of a core-sheath structure, the higher the loss tangent area, the deeper the color. In addition, it can be seen that when the ratio of the sheath component, i.e., polyethylene terephthalate obtained by copolymerization of 7.0 mol% of isophthalic acid and 4.0 mol% of 2,2-bis[4-(2-hydroxyethoxy)phenyl] propane, increased, the friction fastness (staining) decreased.

(Examples 9 and 10)

[0091] Drawn yarns were prepared in the same manner as in Example 7, except that the temperature of the second hot roller during the drawing was changed as shown in Table 2.

[0092] The evaluation results of the fiber properties and the fabric properties of the obtained drawn yarns are shown in Table 2. It can be seen that when the temperature of the second hot roller during the drawing was lowered, the loss tangent area was large, and the color development property was improved.

(Example 11)

[0093] The undrawn yarn obtained in Example 1 was subjected to false twisting using a false twisting device including a 1DR, a 1HT, a cooling plate, a false twister, 2DR, 3DR, 4DR, and a winder, to obtain a false twisted yarn made of a synthetic fiber. The conditions in the false twisting are as follows.

[0094] 1DR speed: 150 m/min, processing ratio between 1DR and 2DR: 2.0 times, 1HT (hot plate type contact heater, length: 2500 mm): 180°C, cooling plate length: 1050 mm, friction disk type friction false twister, ratio between 2DR and 3DR: 1.0 time, ratio between 3DR and 4DR: 1.00 time, ratio between 4DR and winder: 0.98 times.

[0095] The evaluation results of the fiber properties and the fabric properties of the obtained false twisted yarn are shown

in Table 3. The obtained false twisted yarn had a dry heat shrinkage of 5.2% and had an excellent texture even when finish setting was performed after dyeing. In addition, it can be seen that the loss tangent peak value was large, the loss tangent area was large, and the dyeing speed was so fast that the yarn was sufficiently dyed after 5 minutes of dyeing. Further, the difference in pixel value after dyeing between the inner and outer layers was 2.2, and the dyeing was achieved up to the center, indicating that the dye had been sufficiently exhausted and that the color development property was excellent.

(Examples 12 to 14 and Comparative Example 5)

[0096] False twisted yarns were prepared in the same manner as in Example 11, except that the 1HT temperature during the false twisting was changed as shown in Table 3.

[0097] The evaluation results of the fiber properties and the fabric properties of the obtained false twisted yarns are shown in Table 3. It can be seen that when the 1HT temperature during the false twisting was lowered, the loss tangent peak value was increased, but the loss tangent peak temperature was also increased, so that the loss tangent area was smaller and the color development property decreased. In addition, it can be seen that when the 1HT temperature during the false twisting was 200°C, the color development property decreased along with a decrease in dry heat shrinkage, and fusion between single fibers occurred, resulting in a poor texture.

(Comparative Example 6)

[0098] A false twisted yarn was prepared in the same manner as in Example 11, except that proportions of the copolymerization components in the polyethylene terephthalate composition were changed as shown in Table 3 (only use the chip B).

[0099] The evaluation results of the fiber properties and the fabric properties of the obtained false twisted yarn are shown in Table 3. As seen from these results, the loss tangent peak value was small, the dyeing was not sufficiently performed unless the dyeing time was 30 minutes, the difference in pixel value after dyeing between the inner and outer layers was large, and the color development property was poor.

(Example 15)

[0100] The undrawn yarn obtained in Example 7 was used to prepare a false twisted yarn in the same manner as in Example 11.

[0101] The evaluation results of the fiber properties and the fabric properties of the obtained false twisted yarn are shown in Table 4. Due to the core-sheath structure, the dyeing was not sufficiently performed unless the dyeing time was 30 minutes, and the difference in pixel value after dyeing between the inner and outer layers was large, but the loss tangent peak value was large and the loss tangent area was large, so that the color development property was good after dyeing for 30 minutes. As seen from comparison with Example 11 in which the chips were mixed in advance to form a single structure, since polyethylene terephthalate obtained by copolymerization of 7.0 mol% of isophthalic acid and 4.0 mol% of 2,2-bis [4-(2-hydroxyethoxy)phenyl]propane as a sheath component was unevenly distributed on the surface, the friction fastness (staining) was poorer than that of the single structure.

(Examples 16 and 17 and Comparative Examples 7 and 8)

[0102] False twisted yarns were prepared in the same manner as in Example 15, except that the 1HT temperature during the false twisting was changed as shown in Table 4.

[0103] The evaluation results of the fiber properties and the fabric properties of the obtained false twisted yarns are shown in Table 4. It can be seen, in Comparative Example 8, that when the 1HT temperature during the false twisting was 200°C, fusion between single fibers occurred frequently, and it was not possible to obtain a false twisted yarn stably.

(Example 18)

[0104] The undrawn yarn obtained in Example 1 was subjected to false twisting using a false twisting device including a 1DR, a 1HT, a cooling plate, a false twister, 2DR, 3DR, 2HT, 4DR, and a winder, to obtain a false twisted yarn made of a synthetic fiber. The conditions in the false twisting are as follows.

[0105] 1DR speed: 150 m/min, processing ratio between 1DR and 2DR: 2.0 times, 1HT (hot plate type contact heater, length: 2500 mm): 140°C, cooling plate length: 1050 mm, friction disk type friction false twister, ratio between 2DR and 3DR: 1.0 time, 2HT (hot plate type contact heater, length: 2000 mm): 120°C, ratio between 3DR and 4DR: 0.92 times, ratio between 4DR and winder: 0.98 times.

[0106] The evaluation results of the fiber properties and the fabric properties of the obtained false twisted yarn are shown

in Table 5. The obtained false twisted yarn had a dry heat shrinkage of 13.5% and had an excellent texture even when finish setting was performed after dyeing. In addition, it can be seen that the loss tangent peak value was large, the loss tangent area was large, and the dyeing speed was so fast that the yarn was sufficiently dyed after 5 minutes of dyeing. Further, the difference in pixel value after dyeing between the inner and outer layers was 2.4, and the dyeing was achieved up to the center, indicating that the dye had been sufficiently exhausted and that the color development property was excellent.

(Examples 19 to 22)

[0107] False twisted yarns were prepared in the same manner as in Example 18, except that the 1HT temperature and the 2HT temperature during the false twisting were changed as shown in Table 5.

[0108] The evaluation results of the fiber properties and the fabric properties of the obtained false twisted yarns are shown in Table 5. In Example 20, since the 2HT temperature was higher than the 1HT temperature, the heat setting proceeded more, and both the dry heat shrinkage and the crimp recovery rate were small.

[Table 1]

			Example 1	Example 2	Example 3	Example 4
Fiber composition	Form		Single structure	Single structure	Single structure	Single structure
	Basic skeleton		PET	PET	PET	PET
	Copolymerization component (1)	Copolymerization component name	IPA	IPA	IPA	IPA
		Copolymerization amount [mol%]	1.8	0.7	2.8	4.2
	Copolymerization component (2)	Copolymerization component name	BHPP	BHPP	BHPP	BHPP
		Copolymerization amount [mol%]	1.0	0.4	1.6	2.4
	Second hot roller temperature [°C]		130	130	130	130
Fiber properties	Fineness [dtex]		84	84	84	84
	Strength [cN/dtex]		3.9	3.9	3.6	3.6
	Elongation [%]		43.0	44.5	44.5	44.7
	Dry heat shrinkage [%]		10.4	9.9	11.0	13.7
	Melting point (Tm) [°C]		249.8	254.2	247.8	242.0
	Heat Amount of fusion (ΔHm) [J/g]		55.0	57.2	53.4	49.9
	Loss tangent (tan δ)	Peak temperature [°C]	128.2	132.2	126.2	123.3
		Peak value [-]	0.17	0.15	0.18	0.19
		Area [°C]	5.06	4.35	5.54	5.97

(continued)

			Example 1	Example 2	Example 3	Example 4
Fabric properties	Color tone after 5 minutes of dyeing	L* value	16.7	17.3	16.6	16.5
	Color tone after 15 minutes of dyeing	L* value	16.7	17.2	16.6	16.5
	Color tone after 30 minutes of dyeing	L* value	16.7	17.1	16.6	16.5
	Pixel value after dyeing	Fiber exterior	222.5	221.2	223.6	224.2
		Center	154.3	155.5	140.2	128.4
		Outer peripheral portion	151.2	135.5	137.5	125.9
		Difference in inner and outer layers	3.1	20.0	2.7	2.5
	Texture		S	S	A	A
	Friction fastness	Staining [grade]	4 to 5	4 to 5	4 to 5	4
PET: polyethylene terephthalate, IPA: isophthalic acid, BHPP: 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane						

[Table 1] (continued)

			Comparative Example 1	Comparative Example 2	Example 5	Example 6
Fiber composition	Form		Single structure	Single structure	Single structure	Single structure
	Basic skeleton		PET	PET	PET	PET
	Copolymerization component (1)	Copolymerization component name	-	IPA	IPA	IPA
		Copolymerization amount [mol%]	-	7.0	1.8	1.8
	Copolymerization component (2)	Copolymerization component name	-	BHPP	BHPP	BHPP
		Copolymerization amount [mol%]	-	4.0	1.0	1.0
	Second hot roller temperature [°C]		130	130	110	150
Fiber properties	Fineness [dtex]		84	84	84	84
	Strength [cN/dtex]		4.1	3.4	3.7	3.8
	Elongation [%]		41.9	47.1	48.0	43.4
	Dry heat shrinkage [%]		8.8	20.6	13.3	8.4
	Melting point (Tm) [°C]		255.4	227.9	250.5	251.4
	Heat Amount of fusion (ΔHm) [J/g]		59.7	40.0	55.2	56.4
	Loss tangent (tan δ)	Peak temperature [°C]	132.2	114.3	126.4	131.2
		Peak value [-]	0.14	0.22	0.17	0.16
		Area [°C]	4.20	7.88	5.62	4.40

(continued)

			Comparative Example 1	Comparative Example 2	Example 5	Example 6
Fabric properties	Color tone after 5 minutes of dyeing	L* value	18.0	16.1	16.5	17.1
	Color tone after 15 minutes of dyeing	L* value	17.5	16.1	16.5	17.1
	Color tone after 30 minutes of dyeing	L* value	17.2	16.1	16.5	17.1
	Pixel value after dyeing	Fiber exterior	213.7	214.8	222.0	223.8
		Center	144.0	124.4	152.2	161.0
		Outer peripheral portion	116.8	128.7	149.6	148.8
		Difference in inner and outer layers	27.2	-4.3	2.6	12.2
	Texture		S	C	A	S
	Friction fastness	Staining [grade]	4 to 5	3 to 4	4 to 5	4 to 5
PET: polyethylene terephthalate, IPA: isophthalic acid, BHPP: 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane						

[Table 2]

			Example 7	Example 8	Comparative Example 3
Fiber composition	Form		Core-sheath structure	Core-sheath structure	Core-sheath structure
	Core/sheath ratio		75/25	60/40	90/10
	Core component		PET	PET	PET
	Basic skeleton of sheath component		PET	PET	PET
	Sheath component Copolymerization component (1)	Copolymerization component name	IPA	IPA	IPA
		Copolymerization amount [mol%]	7.0	7.0	7.0
	Sheath component Copolymerization component (2)	Copolymerization component name	BHPP	BHPP	BHPP
		Copolymerization amount [mol%]	4.0	4.0	4.0
	Second hot roller temperature [°C]		130	130	130

(continued)

			Example 7	Example 8	Comparative Example 3
Fiber properties	Fineness [dtex]		84	84	84
	Strength [cN/dtex]		4.0	3.9	4.1
	Elongation [%]		40.3	42.5	40.6
	Dry heat shrinkage [%]		11.7	12.7	10.2
	Melting point [°C]		229.6/250.2	230.0/250.1	229.02/249.9
	ΔHm [J/g]	Total	48.7	45.9	51.7
		Detail	7.9/40.8	14.1/31.8	2.3/49.4
	Loss tangent (tan δ)	Peak temperature [°C]	131.2	129.2	134.3
		Peak value [-]	0.15	0.16	0.14
		Area [°C]	4.63	5.34	3.77
Fabric properties	Color tone after 5 minutes of dyeing	L* value	18.2	17.6	19.0
	Color tone after 15 minutes of dyeing	L* value	17.5	17.1	18.0
	Color tone after 30 minutes of dyeing	L* value	17.0	16.7	17.3
	Pixel value after dyeing	Fiber exterior	215.2	217.6	205.7
		Center	172.3	162.8	165.6
		Outer peripheral portion	117.6	117.8	106.1
		Difference in inner and outer layers	54.7	45.0	59.5
	Texture		A	A	S
	Friction fastness	Staining [grade]	4	3 to 4	4 to 5
PET: polyethylene terephthalate, IPA: isophthalic acid, BHPP: 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane					

[Table 2] (continued)

			Comparative Example 4	Example 9	Example 10
Fiber composition	Form		Core-sheath structure	Core-sheath structure	Core-sheath structure
	Core/sheath ratio		40/60	75/25	75/25
	Core component		PET	PET	PET
	Basic skeleton of sheath component		PET	PET	PET
	Sheath component Copolymerization component (1)	Copolymerization component name	IPA	IPA	IPA
		Copolymerization amount [mol%]	7.0	7.0	7.0
	Sheath component Copolymerization component (2)	Copolymerization component name	BHPP	BHPP	BHPP
		Copolymerization amount [mol%]	4.0	4.0	4.0
	Second hot roller temperature [°C]		130	110	150
Fiber properties	Fineness [dtex]		84	84	84
	Strength [cN/dtex]		3.8	4.0	4.2
	Elongation [%]		42.7	44.2	40.6
	Dry heat shrinkage [%]		15.3	14.6	9.8
	Melting point [°C]		229.9/249.8	229.4/249.9	229.7/250.2
	ΔHm [J/g]	Total	43.7	49.3	47.8
		Detail	23.2/20.5	7.9/41.4	7.7/40.1
	Loss tangent (tan δ)	Peak temperature [°C]	123.2	131.0	134.4
		Peak value [-]	0.16	0.15	0.15
		Area [°C]	5.91	5.17	4.05
Fabric properties	Color tone after 5 minutes of dyeing	L* value	17.4	17.8	18.7
	Color tone after 15 minutes of dyeing	L* value	16.9	17.3	17.9
	Color tone after 30 minutes of dyeing	L* value	16.6	16.9	17.3
	Pixel value after dyeing	Fiber exterior	227.6	215.0	217.2
		Center	161.4	170.1	178.5
		Outer peripheral portion	126.8	118.0	120.5
		Difference in inner and outer layers	34.6	52.1	58.0
	Texture		B	A	S
	Friction fastness	Staining [grade]	3 to 4	4	4

PET: polyethylene terephthalate, IPA: isophthalic acid, BHPP: 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane

[Table 3]

			Example 11	Example 12	Example 13
Fiber composition	Form		Single structure	Single structure	Single structure
	Basic skeleton		PET	PET	PET
	Copolymerization component (1)	Copolymerization component name	IPA	IPA	IPA
		Copolymerization amount [mol%]	1.8	1.8	1.8
	Copolymerization component (2)	Copolymerization component name	BHPP	BHPP	BHPP
		Copolymerization amount [mol%]	1.0	1.0	1.0
	1HT temperature [°C]		180	160	140
Fiber properties	Fineness [dtex]		84	84	84
	Strength [cN/dtex]		2.9	3.3	3.4
	Elongation [%]		27.7	33.7	36.2
	Dry heat shrinkage [%]		5.2	7.4	8.2
	Crimp recovery rate [%]		37.5	38.7	35.2
	Melting point (Tm) [°C]		250.2	250.0	249.9
	Heat Amount of fusion (ΔHm) [J/g]		55.1	55.0	55.0
	Loss tangent (tan δ)	Peak temperature [°C]	131.2	132.2	134.2
		Peak value [-]	0.15	0.15	0.16
		Area [°C]	5.90	5.61	5.48
Fabric properties	Color tone after 5 minutes of dyeing	L* value	16.8	17.2	17.5
	Color tone after 15 minutes of dyeing	L* value	16.8	17.1	17.4
	Color tone after 30 minutes of dyeing	L* value	16.8	17.1	17.4
	Pixel value after dyeing	Fiber exterior	220.0	220.4	218.8
		Center	153.3	154.7	153.2
		Outer peripheral portion	151.1	152.3	150.5
		Difference in inner and outer layers	2.2	2.4	2.7
	Texture		S	S	A
	Friction fastness	Staining [grade]	4 to 5	4 to 5	4 to 5
PET: polyethylene terephthalate, IPA: isophthalic acid, BHPP: 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane					

[Table 3] (continued)

			Example 14	Comparative Example 5	Comparative Example 6
Fiber composition	Form		Single structure	Single structure	Single structure
	Basic skeleton		PET	PET	PET
	Copolymerization component (1)	Copolymerization component name	IPA	IPA	-
		Copolymerization amount [mol%]	1.8	1.8	-
	Copolymerization component (2)	Copolymerization component name	BHPP	BHPP	-
		Copolymerization amount [mol%]	1.0	1.0	-
	1HT temperature [°C]		120	200	180
Fiber properties	Fineness [dtex]		84	84	84
	Strength [cN/dtex]		3.5	2.7	4.0
	Elongation [%]		38.2	24.8	29.3
	Dry heat shrinkage [%]		12.2	4.0	7.2
	Crimp recovery rate [%]		32.1	35.4	47.5
	Melting point (Tm) [°C]		249.8	250.1	255.6
	Heat Amount of fusion (ΔHm) [J/g]		54.9	55.1	60.0
	Loss tangent (tan δ)	Peak temperature [°C]	136.1	127.8	135.2
		Peak value [-]	0.16	0.13	0.13
		Area [°C]	5.21	5.01	4.44
Fabric properties	Color tone after 5 minutes of dyeing	L* value	17.8	18.4	19.0
	Color tone after 15 minutes of dyeing	L* value	17.8	18.2	18.4
	Color tone after 30 minutes of dyeing	L* value	17.7	18.0	18.2
	Pixel value after dyeing	Fiber exterior	219.8	225.2	212.8
		Center	155.5	159.2	155.2
		Outer peripheral portion	152.5	155.4	128.9
		Difference in inner and outer layers	3.0	3.8	26.3
	Texture		A	B	A
	Friction fastness	Staining [grade]	4 to 5	4 to 5	4 to 5
PET: polyethylene terephthalate, IPA: isophthalic acid, BHPP: 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane					

[Table 4]

			Example 15	Example 16	Example 17
Fiber composition	Form		Core-sheath structure	Core-sheath structure	Core-sheath structure
	Core/sheath ratio		75/25	75/25	75/25
	Core component		PET	PET	PET
	Basic skeleton of sheath component		PET	PET	PET
	Sheath component Copolymerization component (1)	Copolymerization component name	IPA	IPA	IPA
		Copolymerization amount [mol%]	7.0	7.0	7.0
	Sheath component Copolymerization component (2)	Copolymerization component name	BHPP	BHPP	BHPP
		Copolymerization amount [mol%]	4.0	4.0	4.0
	1HT temperature [°C]		180	160	140
Fiber properties	Fineness [dtex]		84	84	84
	Strength [cN/dtex]		2.9	3.2	3.3
	Elongation [%]		27.7	30.5	34.2
	Dry heat shrinkage [%]		6.9	9.5	10.0
	Crimp recovery rate [%]		21.5	37.2	35.1
	Melting point [°C]		229.8/250.4	229.6/250.2	229.8/250.0
	ΔHm [J/g]	Total	48.6	48.6	48.0
		Detail	7.8/40.8	7.9/40.7	7.9/40.1
	Loss tangent (tan δ)	Peak temperature [°C]	133.2	133.5	134.0
		Peak value [-]	0.15	0.15	0.15
		Area [°C]	5.28	5.23	5.12
Fabric properties	Color tone after 5 minutes of dyeing	L* value	18.1	18.2	18.2
	Color tone after 15 minutes of dyeing	L* value	17.8	18.0	18.0
	Color tone after 30 minutes of dyeing	L* value	17.4	17.6	17.8
	Pixel value after dyeing	Fiber exterior	218.2	220.1	218.9
		Center	174.2	176.9	174.9
		Outer peripheral portion	118.9	124.7	120.8
		Difference in inner and outer layers	55.3	55.2	54.1
	Texture		B	S	A
	Friction fastness	Staining [grade]	4	4	4
PET: polyethylene terephthalate, IPA: isophthalic acid, BHPP: 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane					

[Table 4] (continued)

			Comparative Example 7	Comparative Example 8
Fiber composition	Form		Core-sheath structure	Core-sheath structure
	Core/sheath ratio		75/25	75/25
	Core component		PET	PET
	Basic skeleton of sheath component		PET	PET
	Sheath component Copolymerization component (1)	Copolymerization component name	IPA	IPA
		Copolymerization amount [mol%]	7.0	7.0
	Sheath component Copolymerization component (2)	Copolymerization component name	BHPP	BHPP
		Copolymerization amount [mol%]	4.0	4.0
	1HT temperature [°C]		120	200
Fiber properties	Fineness [dtex]		84	-
	Strength [cN/dtex]		3.5	-
	Elongation [%]		35.2	-
	Dry heat shrinkage [%]		15.2	-
	Crimp recovery rate [%]		35.0	-
	Melting point [°C]		230.2/250.6	-
	ΔHm [J/g]	Total	47.7	-
		Detail	7.7/40.0	-
	Loss tangent (tan δ)	Peak temperature [°C]	134.4	-
		Peak value [-]	0.15	-
		Area [°C]	5.08	-
Fabric properties	Color tone after 5 minutes of dyeing	L* value	18.6	-
	Color tone after 15 minutes of dyeing	L* value	18.2	-
	Color tone after 30 minutes of dyeing	L* value	18.0	-
	Pixel value after dyeing	Fiber exterior	219.8	-
		Center	179.2	-
		Outer peripheral portion	126.3	-
		Difference in inner and outer layers	52.9	-
	Texture		B	-
	Friction fastness	Staining [grade]	4	-
PET: polyethylene terephthalate, IPA: isophthalic acid, BHPP: 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane				

[Table 5]

			Example 18	Example 19	Example 20
Fiber composition	Form		Single structure	Single structure	Single structure
	Basic skeleton		PET	PET	PET
	Copolymerization component (1)	Copolymerization component name	IPA	IPA	IPA
		Copolymerization amount [mol%]	1.8	1.8	1.8
	Copolymerization component (2)	Copolymerization component name	BHPP	BHPP	BHPP
		Copolymerization amount [mol%]	1.0	1.0	1.0
	1HT temperature [°C]		140	140	140
	2HT temperature [°C]		120	140	160
Fiber properties	Fineness [dtex]		84	84	84
	Strength [cN/dtex]		3.3	3.3	3.4
	Elongation [%]		35.2	34.7	34.5
	Dry heat shrinkage [%]		13.5	10.6	5.4
	Crimp recovery rate [%]		27.6	7.0	1.8
	Melting point (Tm) [°C]		249.8	249.8	249.9
	Heat Amount of fusion (ΔHm) [J/g]		55.1	55.1	54.9
	Loss tangent (tan δ)	Peak temperature [°C]	131.2	132.2	129.2
		Peak value [-]	0.15	0.16	0.16
		Area [°C]	4.92	4.60	4.77
Fabric properties	Color tone after 5 minutes of dyeing	L* value	16.6	17.2	16.8
	Color tone after 15 minutes of dyeing	L* value	16.5	17.0	16.7
	Color tone after 30 minutes of dyeing	L* value	16.3	16.7	16.4
	Pixel value after dyeing	Fiber exterior	219.5	223.2	219.8
		Center	154.5	156.2	157.2
		Outer peripheral portion	152.1	152.1	154.9
		Difference in inner and outer layers	2.4	4.1	2.3
	Texture		S	A	A
	Friction fastness	Staining [grade]	4 to 5	4 to 5	4 to 5
PET: polyethylene terephthalate, IPA: isophthalic acid, BHPP: 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane					

[Table 5] (continued)

			Example 21	Example 22
Fiber composition	Form		Single structure	Single structure
	Basic skeleton		PET	PET
	Copolymerization component (1)	Copolymerization component name	IPA	IPA
		Copolymerization amount [mol%]	1.8	1.8
	Copolymerization component (2)	Copolymerization component name	BHPP	BHPP
		Copolymerization amount [mol%]	1.0	1.0
	1HT temperature [°C]		160	180
	2HT temperature [°C]		160	160
Fiber properties	Fineness [dtex]		84	84
	Strength [cN/dtex]		3.4	3.6
	Elongation [%]		35.5	34.6
	Dry heat shrinkage [%]		8.6	10.9
	Crimp recovery rate [%]		4.1	10.1
	Melting point (Tm) [°C]		249.8	250.1
	Heat Amount of fusion (ΔHm) [J/g]		55.0	55.1
	Loss tangent (tan δ)	Peak temperature [°C]	131.2	131.2
		Peak value [-]	0.15	0.14
		Area [°C]	4.80	5.15
Fabric properties	Color tone after 5 minutes of dyeing	L* value	16.7	16.3
	Color tone after 15 minutes of dyeing	L* value	16.6	16.3
	Color tone after 30 minutes of dyeing	L* value	16.4	16.3
	Pixel value after dyeing	Fiber exterior	220.2	227.2
		Center	154.2	158.2
		Outer peripheral portion	152.1	156.2
		Difference in inner and outer layers	2.1	2.0
	Texture		A	S
	Friction fastness	Staining [grade]	4 to 5	4 to 5
PET: polyethylene terephthalate, IPA: isophthalic acid, BHPP: 2,2-bis[4-(2-hydroxyethoxy)phenyl]propane				

INDUSTRIAL APPLICABILITY

[0109] The synthetic fiber according to the present invention provides, in the dyeing step, a synthetic fiber that has an excellent dye exhaustion ability in a dyeing step to thereby make it possible to produce a deep color, that has a fast dyeing speed, that has an excellent texture, and that can be suitably used as a fiber structure.

[0110] Although the present invention has been described in detail with reference to specific embodiments, it is apparent to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the present invention. Note that, the present application is based on a Japanese patent application (No. 2022-134679) filed on August 26, 2022 and a Japanese patent application (No. 2023-31721) filed on March 2, 2023, the contents of which are incorporated herein by reference.

Claims

1. A synthetic fiber, having a loss tangent peak temperature of 100°C or higher and 150°C or lower, a loss tangent peak value of 0.15 or more, and a dry heat shrinkage of 5% or more and less than 15%.

2. The synthetic fiber according to claim 1, having a loss tangent area from 30°C to 130°C of 4.0°C or more and 7.5°C or less.

3. The synthetic fiber according to claim 1 or 2, wherein when a fiber cross section after dyeing to have an L* value of 20 or less is displayed as a 256-level grayscale image, an absolute value of a difference between an average pixel value of a circle that is concentric with a center of an inscribed circle and that has an area of 10% of an area of the fiber cross section and an average pixel value of an outer peripheral portion that has an area of 10% of the area of the fiber cross section is 15 or less.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/030391

A. CLASSIFICATION OF SUBJECT MATTER

D01F 6/84(2006.01)i; ***D01F 8/14***(2006.01)i
FI: D01F6/84 301E; D01F6/84 301J; D01F8/14 B

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2011-196006 A (TORAY INDUSTRIES, INC.) 06 October 2011 (2011-10-06) claims 1, 5, paragraphs [0010], [0042]-[0044], [0046]	1-3
A	JP 2017-43865 A (TORAY INDUSTRIES, INC.) 02 March 2017 (2017-03-02) claims, examples 1-4, 6, 7	1-3
A	JP 4-33887 B2 (ASAHI CHEMICAL INDUSTRY CO., LTD.) 04 June 1992 (1992-06-04) claims	1-3
A	JP 2004-232159 A (KANEBO LTD.) 19 August 2004 (2004-08-19) claims	1-3

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2023	**31 October 2023**
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.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/030391

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2011-196006 A	06 October 2011	(Family: none)	
JP 2017-43865 A	02 March 2017	(Family: none)	
JP 4-33887 B2	04 June 1992	EP 95712 A2 claims JP 58-208415 A JP 58-208416 A US 5108675 A KR 10-1986-0001530 B1	
JP 2004-232159 A	19 August 2004	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H05279917 A **[0008]**
- JP H10204723 A **[0008]**
- JP 2022134679 A **[0110]**
- JP 2023031721 A **[0110]**