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(54) **HIGH-STRENGTH POLYAMIDE 610 MULTIFILAMENT**

(57) A high-strength polyamide 610 multifilament characterized by having a sulfuric acid relative viscosity of 3.0-3.7 and a drying strength of more than 9.2 cN/dtex and within 11.0 cN/dtex. A high-strength polyamide 610 multifilament is provided.

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Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a polyamide 610 multifilament having higher strength than a conventional polyamide 610 multifilament.

BACKGROUND ART

10 **[0002]** Since the multifilaments of polyamide 6 and polyamide 66 have higher strength and elongation and superior fluff quality as compared with general-purpose multifilaments of polyester, polypropylene, and the like, they are used in a wide variety of applications such as airbags, tire cords, racket strings, ropes, fishing nets, and bag belts. In the industrial material fields described above, polyamides 6 and 66 have been used for many years from the viewpoint of high strength and elongation, high abrasion resistance, flexibility, and durability. However, since polyamides 6 and 66 are generally
15 polymers having water and moisture absorbency, in multifilaments of what are called general-purpose polyamides such as polyamide 6 and polyamide 66, strength reduction due to water absorption and dimensional change due to moisture absorption are large. Therefore, there has been the problem that the strength and abrasion resistance are deteriorated by water absorption.

20 **[0003]** Meanwhile, multifilaments of polyamide 11, polyamide 610, polyamide 612, and the like are known as low water absorption polyamide multifilaments, and for example, they have been proposed as fibers for washing brushes (Patent Document 1).

[0004] In addition, as a production method for obtaining a high-strength polyamide multifilament, which is considered to be essential in the industrial material fields, a method of adding a trace amount of moisture to a polymer before melting has been proposed (Patent Document 2).

25 **[0005]** In order to obtain polyamide 6 or 66 having high strength, it is necessary to increase the viscosity of the polymer and increase the draw ratio. However, it is known that since a polymer having high viscosity is rigid, drawability is inhibited in the vicinity of a high draw ratio, so that when the polymer is mechanically forcibly drawn, many molecular chains are broken, yarn breakage occurs, and productivity decreases. Therefore, as a production method for stably obtaining a high-strength polyamide yarn, it has been proposed to adjust the polymer moisture content before melting to a range of
30 0.04 to 0.11 wt% when a polyamide having a high sulfuric acid relative viscosity is melt-spun to produce a filament.

[0006] It has been reported that by adding a small amount of moisture to polyamide 610 chips, in order to provide polyamide 610 multifilaments with high tenacity enough for industrial material applications based on such a technique of adding moisture to general-purpose polyamides 6 and 66 polymers, both a raw yarn strength of 8.5 cN/dtex required for general industrial material fields and good fluff quality are achieved, and it has become possible to provide polyamide
35 610 multifilaments that are low water absorption fibers for industrial material fields (Patent Document 3).

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

40

[0007]

Patent Document 1: Japanese Patent Laid-open Publication No. 2011-1635

Patent Document 2: Japanese Patent Laid-open Publication No. 2014-214405

45 Patent Document 3: International Publication No. 2019/163971

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

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[0008] These polyamide multifilaments produced by the conventional method disclosed in Patent Document 1 have lower strength and poorer fluff quality than those of polyamide 6 and polyamide 66, and thus it has been difficult to develop them for industrial material applications requiring high-strength multifilaments.

55 **[0009]** In the technique disclosed in Patent Document 2, generally, when moisture is added to a polymer before melting, the viscosity of the polymer immediately after melting and discharging decreases with respect to the viscosity of the polymer before melting, and thus a desired high tenacity can be obtained by adjusting production conditions such as an increase in draw ratio, but there has been the problem that the elongation decreases accordingly. As a result, it has been found that as the polymer moisture content increases, the strength-elongation product (toughness) of the filament

decreases, the balance of the physical properties of the filament is lost, a good filament having high tenacity and high elongation cannot be obtained, and the appropriate moisture addition rate to practical polyamide 6 or 66 polymers is limited.

[0010] The technique disclosed in Patent Document 3 has made it possible to provide polyamide 610 multifilaments to industrial material fields, but higher multifilament twisted yarn tenacity is required in applications of tire cords, ropes, and racket strings for which strength and durability of products are particularly emphasized. In order to ensure high tenacity of twisted yarn products by using multifilaments for general industrial materials, it is conceivable to increase the number of doubling to secure strength, but there is the concern that the product weight increases and the cost increases due to the increase in the number of used multifilaments. Therefore, it is required to improve the tenacity of the multifilament itself, but in Patent Document 3, it has been difficult to stably produce a multifilament with a strength exceeding 9 cN/dtex even if polyamide 610 multifilaments suitable for general industrial materials can be provided.

[0011] An object of the present invention is to provide a polyamide multifilament having high strength and low water absorption, which cannot be obtained by conventional techniques.

SOLUTIONS TO THE PROBLEMS

[0012] The present inventors have made intensive studies in order to solve the above-mentioned problems, and the present invention has the following configurations.

(1) A high-strength polyamide 610 multifilament having a sulfuric acid relative viscosity of 3.0 to 3.7 and a dry strength of more than 9.2 cN/dtex and 11.0 cN/dtex or less.

(2) The high-strength polyamide 610 multifilament according to the above (1), having a total fineness of 100 to 2,500 dtex and a single fiber fineness of 1.5 to 40 dtex.

(3) The high-strength polyamide 610 multifilament according to the above (1) or (2), having a birefringence Δn of 50.0×10^{-3} or more.

(4) The high-strength polyamide 610 multifilament according to any one of the above (1) to (3), having a sulfuric acid relative viscosity of 3.0 to 3.3 and a dry strength of more than 9.2 cN/dtex and 11.0 cN/dtex or less.

(5) The high-strength polyamide 610 multifilament according to any one of the above (1) to (4), having change rates of strength, elongation, and intermediate elongation in a wet state of all 10% or less.

(6) A rope including the high-strength polyamide 610 multifilament according to any one of the above (1) to (5).

(7) A racket string including the high-strength polyamide 610 multifilament according to any one of the above (1) to (5).

(8) A textile for a bag fabric, including the high-strength polyamide 610 multifilament according to any one of the above (1) to (5).

(9) A fishing net including the high-strength polyamide 610 multifilament according to any one of the above (1) to (5).

EFFECTS OF THE INVENTION

[0013] With the present invention, it is possible to provide a polyamide 610 multifilament having high strength, which is realized by polyamide 6 and polyamide 66 multifilaments.

BRIEF DESCRIPTION OF THE DRAWING

[0014] Fig. 1 schematically shows a direct spinning/drawing machine preferably used in the present invention.

EMBODIMENT OF THE INVENTION

[0015] Raw material chips (hereinafter also simply referred to as chips) of a high-strength polyamide 610 multifilament of the present invention are polyamide 610 chips. The chips are preferably composed only of polyamide 610, but it is sufficient that the chips are substantially composed of polyamide 610, and other polymers may be mixed or copolymerized within a range not impairing the characteristics of the present invention, specifically, within a range of 5 mass% or less. As the polymer copolymerization unit to be mixed or copolymerized, polyamides such as polyamides 6, 66, 11, and 12 are preferable.

[0016] The sulfuric acid relative viscosity (hereinafter also simply referred to as the viscosity) of raw material chips of the high-strength polyamide 610 multifilament of the present invention is preferably 3.6 to 4.0, more preferably 3.7 to 3.9, still more preferably 3.7 to 3.8. If the viscosity of the chips is less than 3.6, when the moisture content of the chips is within the following preferable range, the viscosity of the polyamide 610 multifilament is excessively reduced, and it may be difficult to sufficiently obtain the dry strength. If the viscosity exceeds 4.0, the melt viscosity of the polymer in the spinning machine increases, and dischargeability from the spinneret, spinnability, or drawability may be impaired.

The sulfuric acid relative viscosity refers to a value obtained by dissolving a sample in 98% sulfuric acid and measuring the sulfuric acid relative viscosity at 25°C using an Ostwald viscometer.

[0017] The polyamide 610 as a raw material of the polyamide 610 multifilament of the present invention preferably has a chip moisture content of 0.15 wt% or more, more preferably 0.20 to 0.35 wt%, particularly preferably 0.25 to 0.35 wt%. In order to obtain the high-strength polyamide 610 multifilament of the present invention, it is important to further improve drawability by increasing the moisture content and decreasing the melt viscosity as compared with the prior art. Furthermore, since water molecules penetrate into the polyamide molecular chain because of the high moisture addition rate described above to cause a plasticizing effect, drawability is greatly improved, and an improvement in the critical draw ratio is achieved. Due to these multiple effects, the high-strength polyamide 610 multifilament can be obtained. As a method for adjusting the moisture content, a method of adding measured water to dried chips and stirring the chips is preferable, but any method may be used as long as the above range is achieved.

[0018] The sulfuric acid relative viscosity (hereinafter also simply referred to as the viscosity) of the high-strength polyamide 610 multifilament of the present invention needs to be 3.0 to 3.7, more preferably 3.0 to 3.5, still more preferably 3.0 to 3.3. When the viscosity of the multifilament is less than 3.0, a raw yarn having sufficient strength cannot be obtained, and when the viscosity exceeds 3.7, drawability and fluff quality may be deteriorated.

[0019] In applications of tire cords, ropes, and racket strings, weight reduction of products and the like are emphasized, and in order to satisfy the weight reduction, the dry strength of the polyamide 610 multifilament of the present invention needs to be more than 9.2 cN/dtex and 11.0 cN/dtex or less. The strength is more preferably within 9.5 to 11.0 cN/dtex.

[0020] Although it is difficult to produce high-strength fibers exceeding 9.2 cN/dtex by a normal method, the high-strength polyamide 610 multifilament can be obtained by adjusting the high moisture content used in the present invention and achieving the following chip viscosity and the viscosity range of the multifilament.

[0021] As a result of intensive studies, the present inventors have found that in order to obtain a high-strength polyamide 610 multifilament having a dry strength exceeding 9.2 cN/dtex, it is important to improve drawability in a drawn portion as compared with the prior art and to realize high ratio drawing. For this purpose, the present inventors have found that it is necessary to set the viscosity of the polyamide 610 multifilament to 3.0 to 3.7 by setting the viscosity of the raw material chips to 3.6 to 4.0 and the moisture content to 0.2 to 0.35 wt%. In the case of polyamides 6 and 66, when the moisture content is 0.2 wt% or more, moisture in the polymer becomes excessive, the equilibrium state between polymerization and decomposition of the polymer greatly shifts to the decomposition side during heating of melt spinning, the polymer is decomposed, and the decrease in melt viscosity becomes large. Accordingly, as a result of setting the draw ratio in the drawn portion to be excessively high in order to ensure high tenacity, there is the problem that the elongation decreases and fluff is generated due to an increase in mechanical load. On the other hand, in polyamide 610, surprisingly, the phenomenon in which a decrease in melt viscosity is observed is similar, but the elongation is maintained even when the draw ratio is set to be high, and as a result, it is possible to obtain a multifilament having high strength and high elongation. This is considered to be because water molecules act as a plasticizer in the polyamide 610 molecules. In fact, in the high-tenacity polyamide 610 multifilament that is enabled to be drawn at a high ratio by adding moisture at a ratio of 0.2 to 0.35 wt%, the degree of orientation described later is increased, suggesting that the drawability is improved by the presence of water molecules.

[0022] The elongation is preferably 15% or more, more preferably 17% or more. Polyamide 610 multifilaments having an elongation of less than 15% significantly deteriorate the fluff quality in the spinning process, and yarn breakage in the drawing process increases, so that productivity may be poor.

[0023] The polyamide 610 multifilament of the present invention preferably has change rates of strength, elongation, and intermediate elongation in a wet state of all 10% or less. The change rates are more preferably all 5% or less, still more preferably all 2% or less. When the change rates of the strength, elongation, and intermediate elongation in a wet state is 10% or less, the change in the strength/elongation curve, what is called an SS curve, in a wet state can be suppressed as compared with polyamide 6 or polyamide 66, which is a general-purpose polyamide. As a result, it is possible to suppress a decrease in the strength of the fiber product due to water absorption caused by rainfall outdoors or use on the sea, and it is possible to provide a product excellent in dimensional stability by suppressing a change in the SS curve. This characteristic is exhibited in the polyamide 610 multifilament having low water absorbency and is also an important characteristic because maintaining product strength is one of required characteristics particularly in high-strength applications. The change rates of these characteristics are degrees of change from values in a dry state to values in a wet state and refer to values measured by a method described later.

[0024] The total fineness of the polyamide 610 multifilament of the present invention is preferably 100 to 2,500 dtex, more preferably 100 to 2,000 dtex. When the total fineness exceeds 2,500 dtex, the polymer output from the spinneret increases, and the cooling of the yarn immediately after spinning is insufficient, so that a multifilament having sufficient strength may not be obtained.

[0025] The single fiber fineness is preferably 1.5 to 40 dtex, more preferably 1.5 to 15 dtex. A polyamide 610 multifilament having a single fiber fineness of less than 1.5 dtex has low abrasion resistance with drawing rolls in the spinning process, and thus the fluff quality may deteriorate when the draw ratio is increased to obtain high-strength fibers. On

the other hand, if the single fiber fineness exceeds 40 dtex, it may be difficult to cool the polymer in the spinning process, and sufficient strength may not be obtained.

[0026] The birefringence Δn of the high-strength polyamide 610 multifilament of the present invention is preferably 50.0×10^{-3} or more, more preferably 52.0×10^{-3} or more. The birefringence of the multifilament is an index indicating the degree of orientation of molecules, and it is considered that in the high-strength polyamide 610 multifilament of the present invention, when a high ratio of moisture is added to the raw material chips, a sufficient amount of water molecules is present in the polyamide molecules, and the water molecules exhibit a plasticizer effect, thereby improving drawability. By improving the drawability, the mechanical draw ratio can be increased, and the degree of molecular orientation, that is, the birefringence of the resulting multifilament is further increased. As for the polyamide multifilament, as the degree of molecular orientation increases, oriented crystallization also sequentially proceeds and increases, so that the strength of the multifilament tends to increase. The birefringence Δn is a value measured using a polarization microscope described later.

[0027] Next, a method for producing the high-strength polyamide 610 multifilament of the present invention will be described. The polyamide 610 multifilament can be preferably produced by the following method based on normal melt spinning, but in the present invention, it is particularly effective to produce the polyamide 610 filament by a direct spinning/drawing method. In addition, when melt spinning is performed, it is preferable to control the viscosity of the chips to an appropriate viscosity and then impart a predetermined amount of moisture, whereby the strength and elongation can be improved, and yarn breakage and generation of fluff during drawing can be suppressed. As a result, the polyamide 610 multifilament having high strength can be obtained.

[0028] Hereinafter, description will be given using Fig. 1 as an example.

[0029] Fig. 1 schematically shows a direct spinning/drawing machine preferably used in the present invention.

[0030] Polyamide 610 chips having adjusted viscosity, moisture content, and the like are melted and kneaded with an extruder type spinning machine (not illustrated in Fig. 1) and spun by being discharged from a spinneret 1 in a spinning section. The spinning temperature is generally higher than the melting point of the target polymer by 30°C or more. When the temperature is lower than 30°C, the polymer is not uniformly melted due to insufficient heat quantity, and the melt viscosity is also increased, so that the spinnability becomes unstable. Spun yarns 5 spun from the spinneret 1 pass through a heating cylinder 2 and are cooled by cooling air 4 with a crossflow cooling device 3. The cooled yarns 5 pass through a duct 6 and are taken up by take-up rollers 8 while being supplied with a treatment agent by oiling devices 7. The taken-up yarns 5 are subjected to pre-stretch drawing between the take-up rollers 8 and a take-up roller 9. Thereafter, the yarns are drawn in three stages by first drawing rollers 10, second drawing rollers 11, and third drawing rollers 12 and relaxed by relaxation rollers 13. The relaxed yarns 5 are entangled by an entangling device 14 and wound by a winder 15 to form a fiber package 16.

[0031] As described above, the viscosity of the polyamide 610 chips used as a raw material is preferably 3.6 to 4.0, and the moisture content is preferably 0.2 wt% or more.

[0032] In the above, the take-up speed at the time of take-up is 350 to 1,100 m/min, preferably 400 to 800 m/min. The treatment agent in the present invention is preferably used as a nonaqueous treatment agent, but sufficient physical properties can be obtained even when a water-containing treatment agent is used. The method for applying the treatment agent is preferably an oiling roll device or a guide oiling.

[0033] The process from drawing to winding is preferably performed by a method in which the yarn is drawn in usually two or more stages and then relaxed to be wound up. When drawing is performed in two or more stages, it is preferable to perform pre-stretch drawing and then perform drawing. It is preferable that the pre-stretch drawing and the first stage drawing be performed by heat drawing at around the glass transition temperature, and the remaining drawing and heat setting temperature be usually performed at a high temperature of 150 to 220°C. The temperature is more preferably 170 to 210°C.

[0034] The draw ratio, that is, the ratio between the take-up rollers 8 and the second drawing rollers 11, is usually in the range of 3 to 6 times. Note that the winding speed is usually preferably 2,000 to 5,000 m/min, more preferably 2,000 to 4,000 m/min. In addition, it is preferable to wind up the yarn to form a cheese thread with the winding device under the condition of a winding tension of 20 to 250 gf.

[0035] The polyamide 610 multifilament of the present invention can be produced by the above method.

EXAMPLES

[0036] Hereinafter, the present invention will be described in detail on the basis of examples, but the present invention is not limited thereto at all. The measurement method of each measured value in the examples is as follows.

(1) Sulfuric acid relative viscosity (η_r): Using polymer chips or raw yarns (filaments) as a sample, 0.25 g of the sample was dissolved in 25 mL of 98% sulfuric acid, the solution was measured at 25°C using an Ostwald viscometer, and the viscosity was determined from the following formula. The measured value was calculated from the average

value of five samples.

n_r = the number of seconds that the sample solution
flows down/the number of seconds that only sulfuric acid
flows down.

(2) Moisture content: HIRANUMA Coulometric Karl Fischer Titrator "AQ-2200" available from Hiranuma Sangyo Co., Ltd. and "Solid Evaporator "EV-2000" available from Hiranuma Sangyo Co., Ltd. were used in combination for measurement. That is, the moisture in the sample chips was extracted using EV-2000 available from Hiranuma Sangyo Co., Ltd., and the moisture content was measured using AQ-2200 available from Hiranuma Sangyo Co., Ltd. The sample weighed 1.5 g, and the nitrogen used for moisture vaporization was 0.2 L/min.

[0037] The measurement conditions were as follows.

- Step 1: temperature 210°C, time 21 min
- Pre-heating time: 0 min
- End B.G.: 0 µg
- Cooling time: 1 min
- B.G. stable count: 30
- Back purge time: 20 seconds.

[0038] (3) Total fineness: The fineness based on corrected weight was measured under a predetermined load of 0.045 cN/dtex according to JIS L 1013 (2010) 8.3.1 method A and taken as the total fineness.

[0039] (4) Number of filaments: The number of filaments was calculated by the method according to JIS L 1013 (2010) 8.4.

[0040] (5) Single fiber fineness: (3) The total fineness was divided by (4) the number of filaments.

[0041] (6) Tenacity/strength/elongation (in dry state):

The measurement was performed under constant speed elongation conditions defined in JIS L 1013 (2010) 8.5.1, Standard Time Test. A sample was measured using "TENSILON" UCT-100 manufactured by ORIENTEC CORPORATION, at a holding interval of 250 mm and a tensile speed of 300 mm/min. The tenacity and elongation were determined from the maximum tenacity and maximum elongation in the S-S curve, and the strength was determined by dividing the tenacity by the total fineness.

[0042] Intermediate elongation (in dry state): According to JIS L 1017 (2002) 8.7 a), an elongation at a constant load F (N) in the following formula was calculated as an intermediate elongation using a standard fineness of 940 dtex.

$$F = 44 \times D/940$$

F : constant load (N), D : (3) total fineness (dtex).

[0043] (7) Tenacity/strength/elongation (in wet state):

A small skein having a predetermined yarn length was produced in the manner of JIS L 1013 (2010) 8.3.1 method A, and the small skein was immersed in tap water at 20°C for 24 hours. After a lapse of 24 hours, the small skein was taken out and measured within 10 minutes under constant speed elongation conditions defined in JIS L 1013 (2010) 8.5.1, Standard Time Test. The tenacity and elongation were determined from the maximum tenacity and maximum elongation in the S-S curve, and the strength was determined by dividing the tenacity by the total fineness.

[0044] Intermediate elongation (in wet state): According to JIS L 1017 (2002) 8.7 a), an elongation at a constant load F (N) in the following formula was calculated as an intermediate elongation using a standard fineness of 940 dtex.

$$F = 44 \times D/940$$

F : constant load (N), D : (3) total fineness (dtex)

[0045] The difference between each of the wet strength, the wet elongation, and the wet intermediate elongation obtained in this measurement and the value in a dry state was determined, and the absolute values of the differences were respectively divided by the dry strength, the dry elongation, and the dry intermediate elongation and expressed as

percentages, so that the wet strength change rate, the wet elongation change rate, and the wet intermediate elongation change rate were calculated.

[0046] (8) Birefringence Δn : Measurement was performed using a molecular orientation measurement device (Type: DELT_N-IIH) manufactured by INTEC Co., Ltd. Paraffin was added dropwise to a slide glass, one filament single fiber was placed on the slide glass, and the slide glass was covered with a cover glass from above. The slide glass was set in a polarizing microscope, and both ends of the single yarn were focused. A waveplate was inserted into the microscope to adjust a wavelength λ at which black stripes were generated at both ends of the single yarn. In this measurement, waveplates were combined to achieve 2.5λ . Thereafter, a single yarn diameter D was measured by image processing. Subsequently, a distance L between two black interference fringes existing on both sides was measured.

[0047] In principle, Δn is obtained by $\Delta n = R/d$ (R: optical path difference, d: transmission distance), but in the present device, Δn is automatically calculated by measuring the optical path difference R from the wavelength of the waveplate and the single yarn diameter D and the interval L of the black interference fringes by image processing.

[Example 1]

[0048] A 5-wt% aqueous solution of copper acetate as an antioxidant was added to and mixed with polyamide 610 (N610) chips obtained by liquid phase polymerization, and 70 ppm of copper was added and adsorbed relative to the polymer weight. Next, a 50-wt% aqueous solution of potassium iodide and a 20-wt% aqueous solution of potassium bromide were each added and adsorbed so as to be 0.1 parts by weight as potassium with respect to 100 parts by weight of the polymer chips, solid-phase polymerization was performed using a solid-phase polymerization apparatus, and then moisture was added to obtain polyamide 610 chips having a sulfuric acid relative viscosity of 3.80 and a moisture content of 0.31 wt%.

[0049] As the spinning device, the device of Fig. 1 was used. The polyamide 610 chips were supplied to an extruder, and the discharge amount was adjusted by a metering pump so that the total fineness was about 470 dtex. The spinning temperature was 285°C, and the product was filtered through a metal nonwoven fabric filter in a spinning pack and then spun through a spinneret having 48 holes. The spun yarns were passed through a heating cylinder heated to a temperature of 250°C and then cooled and solidified by cooling air at an air speed of 40 m/min. A water-containing treatment agent was applied to the cooled and solidified yarns by the oiling devices 7, and the yarns were swirled by spinning take-up rollers to take up the yarns. The taken-up yarns were then subjected to 5% stretching between the take-up rollers 8 and the take-up roller 9 without being wound up once, then subjected to first stage drawing between the take-up roller 9 and the first drawing rollers 10 so that the rotation speed ratio between the rollers was 2.55, and subsequently subjected to second stage drawing between the first drawing rollers 10 and the second drawing rollers 11 so that the rotation speed ratio between the rollers was 1.35. Subsequently, third stage drawing was performed between the second drawing rollers 11 and the third drawing rollers 12 such that the rotation speed ratio between the rollers was 1.65. The rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was set to 6.0.

[0050] Subsequently, 5% relaxation heat treatment was performed between the third drawing rollers 12 and the relaxation rollers 13, and the yarns were entangled by the entangling device 14 and then wound by the winding device 15. The surface temperature of each roller was set so that the take-up rollers were at room temperature, yarn feeding rollers at 45°C, the first drawing rollers at 95°C, the second drawing rollers at 150°C, the third drawing rollers at 200°C, and the relaxation rollers at 140°C. The entangling treatment was performed by injecting highpressure air from a direction perpendicular to the traveling yarns in the entangling device. A guide for regulating the traveling yarns was provided before and after the entangling device, and the pressure of the injected air was constant at 0.2 MPa. Under the above conditions, a 470-dtex polyamide 610 multifilament was obtained.

[0051] The obtained multifilament had very high drawability and could be drawn at a high ratio. A dry strength of 10.1 cN/dtex was obtained. Since the birefringence of the multifilament was as high as 58.2, it is suggested that oriented crystallization in the multifilament has been sufficiently promoted. A multifilament in which all of the wet strength change rate, the wet elongation change rate, and the wet intermediate elongation change were 5% or less, the multifilament being excellent in suppression of deterioration in physical properties in a wet state and dimensional stability, was obtained.

[Example 2]

[0052] Chips were subjected to solid phase polymerization in the same manner as in Example 1, and moisture was added to obtain polyamide 610 chips having a sulfuric acid relative viscosity of 3.80 and a moisture content of 0.25 wt%.

[0053] Production was carried out in the same manner as in Example 1 except that the moisture content of the chips was adjusted.

[0054] The obtained multifilament had very high drawability and could be drawn at a high ratio while the moisture content was 0.25 wt%. A dry strength of 10.0 cN/dtex was obtained. Since the birefringence of the multifilament was as high as 55.2, it is suggested that oriented crystallization in the multifilament has been sufficiently promoted. The evaluation

results of the tensile test in a wet state are shown in Table 1.

[Example 3]

[0055] Chips were subjected to solid phase polymerization in the same manner as in Example 1, and moisture was added to obtain polyamide 610 chips having a sulfuric acid relative viscosity of 3.80 and a moisture content of 0.21 wt%.

[0056] Production was carried out in the same manner as in Example 1 except that the third stage drawing was carried out between the second drawing rollers 11 and the third drawing rollers 12 so that the rotation speed ratio between the rollers was 1.59 and that the rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was changed to 5.75.

[0057] The obtained multifilament had high drawability and could be drawn at a high ratio while the moisture content was 0.21 wt%. A dry strength of 9.8 cN/dtex was obtained. Since the birefringence of the multifilament was as relatively high as 52.3, it is suggested that oriented crystallization in the multifilament has been promoted. The evaluation results of the tensile test in a wet state are shown in Table 1.

[Example 4]

[0058] Chips were subjected to solid phase polymerization in the same manner as in Example 1, and moisture was added to obtain polyamide 610 chips having a sulfuric acid relative viscosity of 3.80 and a moisture content of 0.25 wt%.

[0059] Production was carried out in the same manner as in Example 1 except that the third stage drawing was carried out between the second drawing rollers 11 and the third drawing rollers 12 so that the rotation speed ratio between the rollers was 1.59 and that the rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was changed to 5.75.

[0060] The obtained multifilament had very high drawability and could be drawn at a high ratio while the moisture content was 0.25 wt%. A dry strength of 9.6 cN/dtex was obtained. Since the birefringence of the multifilament was as high as 53.8, it is suggested that oriented crystallization in the multifilament has been sufficiently promoted. The evaluation results of the tensile test in a wet state are shown in Table 1.

[Example 5]

[0061] Chips were subjected to solid phase polymerization in the same manner as in Example 1, and moisture was added to obtain polyamide 610 chips having a sulfuric acid relative viscosity of 3.80 and a moisture content of 0.22 wt%.

[0062] The discharge amount was adjusted with a metering pump so that the total fineness was about 970 dtex, and spinning was performed through a spinneret having 204 holes.

[0063] Production was carried out in the same manner as in Example 1 except that, in the take-up and drawing, the third stage drawing was carried out between the second drawing rollers 11 and the third drawing rollers 12 so that the rotation speed ratio between the rollers was 1.50 and that the rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was changed to 5.42.

[0064] The obtained multifilament had high drawability and could be drawn at a high ratio while the moisture content was 0.22 wt%, the total fineness was 970 dtex, and the number of filaments was 204. A dry strength of 9.4 cN/dtex was obtained. Since the birefringence of the multifilament was as relatively high as 51.6, it is suggested that oriented crystallization in the multifilament has been sufficiently promoted. The evaluation results of the tensile test in a wet state are shown in Table 1.

[Example 6]

[0065] Chips were subjected to solid phase polymerization in the same manner as in Example 1, and moisture was added to obtain polyamide 610 chips having a sulfuric acid relative viscosity of 3.79 and a moisture content of 0.15 wt%.

[0066] Production was carried out in the same manner as in Example 1 except that the third stage drawing was carried out between the second drawing rollers 11 and the third drawing rollers 12 so that the rotation speed ratio between the rollers was 1.55 and that the rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was changed to 5.60.

[0067] The obtained multifilament had high drawability and could be drawn at a high ratio while the moisture content was 0.15 wt%. A dry strength of 9.7 cN/dtex was obtained. Since the birefringence of the multifilament was as relatively high as 52.0, it is suggested that oriented crystallization in the multifilament has been sufficiently promoted. The evaluation results of the tensile test in a wet state are shown in Table 1.

[Example 7]

[0068] Chips were subjected to solid phase polymerization in the same manner as in Example 1, and moisture was added to obtain polyamide 610 chips having a sulfuric acid relative viscosity of 3.78 and a moisture content of 0.26 wt%.

[0069] The discharge amount was adjusted with a metering pump so that the total fineness was about 235 dtex, and spinning was performed through a spinneret having 136 holes.

[0070] Production was carried out in the same manner as in Example 1 except that the take-up and drawing were performed at a rotation speed ratio of 2.40 between the take-up roller 9 and the first drawing rollers 10 in the first stage drawing, a rotation speed ratio of 1.35 between the first drawing rollers 10 and the second drawing rollers 11 in the second stage drawing, a rotation speed ratio of 1.41 between the second drawing rollers 11 and the third drawing rollers 12 in the third stage drawing, and a rotation speed ratio of 4.80 between the take-up rollers 8 and the third drawing rollers 12.

[0071] The obtained multifilament had extremely high drawability and could be drawn at a high ratio while the moisture content was 0.26 wt%, the total fineness was 235 dtex, and the number of filaments was 136. A dry strength of 9.3 cN/dtex was obtained. Since the birefringence of the multifilament was as high as 54.2, it is suggested that oriented crystallization in the multifilament has been sufficiently promoted. The evaluation results of the tensile test in a wet state are shown in Table 1.

[Example 8]

[0072] Chips were subjected to solid phase polymerization in the same manner as in Example 1, and moisture was added to obtain polyamide 610 chips having a sulfuric acid relative viscosity of 3.81 and a moisture content of 0.25 wt%.

[0073] The discharge amount was adjusted with a metering pump so that the total fineness was about 1,400 dtex, and spinning was performed through a spinneret having 204 holes.

[0074] Production was carried out in the same manner as in Example 1 except that the take-up and drawing were performed at a rotation speed ratio of 2.70 between the take-up roller 9 and the first drawing rollers 10 in the first stage drawing, a rotation speed ratio of 1.35 between the first drawing rollers 10 and the second drawing rollers 11 in the second stage drawing, a rotation speed ratio of 1.46 between the second drawing rollers 11 and the third drawing rollers 12 in the third stage drawing, and a rotation speed ratio of 5.60 between the take-up rollers 8 and the third drawing rollers 12.

[0075] The obtained multifilament had high drawability and could be drawn at a high ratio while the moisture content was 0.25 wt%, the total fineness was 1,400 dtex, and the number of filaments was 204. A dry strength of 9.3 cN/dtex was obtained. Since the birefringence of the multifilament was as relatively high as 51.3, it is suggested that oriented crystallization in the multifilament has been sufficiently promoted. The evaluation results of the tensile test in a wet state are shown in Table 1.

[Comparative Example 1]

[0076] Chips were subjected to solid phase polymerization in the same manner as in Example 1, and moisture was added to obtain polyamide 610 chips having a sulfuric acid relative viscosity of 3.82 and a moisture content of 0.05 wt%.

[0077] In the same manner as in Example 1, the polyamide 610 chips were supplied to an extruder, and the discharge amount was adjusted by a metering pump so that the total fineness was about 470 dtex. The spinning temperature was 285°C, and the product was filtered through a metal nonwoven fabric filter in a spinning pack and then spun through a spinneret having 48 holes. The spun yarns were passed through a heating cylinder heated to a temperature of 250°C and then cooled and solidified by cooling air at an air speed of 40 m/min. A water-containing treatment agent was applied to the cooled and solidified yarns by the oiling devices 7, and the yarns were swirled by spinning take-up rollers to take up the yarns. The taken-up yarns were then subjected to 5% stretching between the take-up rollers 8 and the take-up roller 9 without being wound up once, then subjected to first stage drawing between the take-up roller 9 and the first drawing rollers 10 so that the rotation speed ratio between the rollers was 2.55, and subsequently subjected to second stage drawing between the first drawing rollers 10 and the second drawing rollers 11 so that the rotation speed ratio between the rollers was 1.35. Subsequently, third stage drawing was performed between the second drawing rollers 11 and the third drawing rollers 12 such that the rotation speed ratio between the rollers was 1.35. The rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was set to 4.9.

[0078] Subsequently, 5% relaxation heat treatment was performed between the third drawing rollers 12 and the relaxation rollers 13, and the yarns were entangled by the entangling device 14 and then wound by the winding device 15. The surface temperature of each roller was set so that the take-up rollers were at room temperature, yarn feeding rollers at 45°C, the first drawing rollers at 95°C, the second drawing rollers at 150°C, the third drawing rollers at 200°C, and the relaxation rollers at 140°C. The entangling treatment was performed by injecting highpressure air from a direction

perpendicular to the traveling yarns in the entangling device. A guide for regulating the traveling yarns was provided before and after the entangling device, and the pressure of the injected air was constant at 0.2 MPa. Under the above conditions, a 470-dtex polyamide 610 multifilament was obtained.

[0079] The obtained multifilament had insufficient drawability, and the limit of the rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was about 5 times. The dry strength at this time was only about 8.8 cN/dtex. The birefringence of the multifilament was 47.0, which was lower than that of the multifilament of the present invention. The evaluation results of the tensile test in a wet state are shown in Table 2.

[Comparative Example 2]

[0080] Solid phase polymerization of chips was performed in the same manner as in Example 1, and no moisture was added. The obtained polyamide 610 chips had a sulfuric acid relative viscosity of 3.82 and a moisture content of 0.02 wt%.

[0081] Production was carried out in the same manner as in Comparative Example 1 except that the moisture content of the chips was changed.

[0082] The obtained multifilament had insufficient drawability, and the limit of the rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was about 5 times. The dry strength at this time was only about 8.9 cN/dtex.

[0083] A guide for regulation was provided, and the pressure of the injected air was constant at 0.2 MPa. Under the above conditions, a 470-dtex polyamide 610 multifilament was obtained. The birefringence of the multifilament was 47.2, which was lower than that of the multifilament of the present invention. The evaluation results of the tensile test in a wet state are shown in Table 2.

[Comparative Example 3]

[0084] Solid phase polymerization of chips was performed in the same manner as in Example 1, and no moisture was added. The obtained polyamide 610 chips had a sulfuric acid relative viscosity of 4.00 and a moisture content of 0.02 wt%.

[0085] Production was carried out in the same manner as in Example 1 except that the third stage drawing was carried out between the second drawing rollers 11 and the third drawing rollers 12 so that the rotation speed ratio between the rollers was 1.24 and that the rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was changed to 4.50.

[0086] The obtained multifilament had poor drawability, and the limit of the rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was about 4.5 times. The dry strength at this time was only about 8.3 cN/dtex, and the fluff quality was not good. The birefringence of the multifilament was 46.3, which was lower than that of the multifilament of the present invention. The evaluation results of the tensile test in a wet state are shown in Table 2.

[Comparative Example 4]

[0087] Chips obtained by liquid phase polymerization was changed from polyamide 610 chips to polyamide 6 chips, a 5-wt% aqueous solution of copper acetate as an antioxidant was added and mixed, and 70 ppm of copper was added and adsorbed relative to the polymer weight. Next, a 50-wt% aqueous solution of potassium iodide and a 20-wt% aqueous solution of potassium bromide were each added and adsorbed so as to be 0.1 parts by weight as potassium with respect to 100 parts by weight of the polymer chips, solid-phase polymerization was performed using a solid-phase polymerization apparatus, and then moisture was added to obtain polyamide 6 chips having a sulfuric acid relative viscosity of 3.80 and a moisture content of 0.05 wt%.

[0088] In the same manner as in Example 1, the polyamide 6 chips were supplied to an extruder, and the discharge amount was adjusted by a metering pump so that the total fineness was about 2,100 dtex. The spinning temperature was 285°C, and the product was filtered through a metal nonwoven fabric filter in a spinning pack and then spun through a spinneret having 306 holes. The spun yarns were passed through a heating cylinder heated to a temperature of 315°C and then cooled and solidified by cooling air at an air speed of 35 m/min. A water-containing treatment agent was applied to the cooled and solidified yarns by the oiling devices 7, and the yarns were swirled by spinning take-up rollers to take up the yarns. The taken-up yarns were then subjected to 7% stretching between the take-up rollers 8 and the take-up roller 9 without being wound up once, then subjected to first stage drawing between the take-up roller 9 and the first drawing rollers 10 so that the rotation speed ratio between the rollers was 2.90, and subsequently subjected to second stage drawing between the first drawing rollers 10 and the second drawing rollers 11 so that the rotation speed ratio between the rollers was 1.50. Subsequently, third stage drawing was performed between the second drawing rollers 11 and the third drawing rollers 12 such that the rotation speed ratio between the rollers was 1.15. The rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was set to 5.37.

[0089] Subsequently, 8% relaxation heat treatment was performed between the third drawing rollers 12 and the relaxation rollers 13, and the yarns were entangled by the entangling device 14 and then wound by the winding device

15. The surface temperature of each roller was set so that the take-up rollers were at room temperature, yarn feeding rollers at 45°C, the first drawing rollers at 105°C, the second drawing rollers at 180°C, the third drawing rollers at 200°C, and the relaxation rollers at 145°C. The entangling treatment was performed by injecting highpressure air from a direction perpendicular to the traveling yarns in the entangling device. A guide for regulating the traveling yarns was provided before and after the entangling device, and the pressure of the injected air was constant at 0.3 MPa. Under the above conditions, a 2,100-dtex polyamide 6 multifilament was obtained.

[0090] The obtained multifilament had such drawability that the limit of the rotation speed ratio between the take-up rollers 8 and the third drawing rollers 12 was about 5.6 times. The dry strength at this time was only about 9.2 cN/dtex. The birefringence of the multifilament was 48.2, which was lower than that of the polyamide 610 multifilament of the present invention. The evaluation results of the tensile test in a wet state are shown in Table 2, and since the polyamide 6 multifilament was used, the decrease in strength in the wet state was large.

[Table 1]

Form	Item	Unit	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8
Chip	Type of polymer	-	N610	N610	N610	N610	N610	N610	N610	N610
	Sulfuric acid relative viscosity	-	3.80	3.80	3.80	3.80	3.80	3.79	3.78	3.81
	Moisture content	%	0.31	0.25	0.21	0.25	0.22	0.15	0.26	0.25
Multifilament	Sulfuric acid relative viscosity	-	3.11	3.19	3.30	3.21	3.45	3.51	3.08	3.51
	Total fineness	dtex	470	470	470	470	970	470	235	1400
	Number of filaments	-	48	48	48	48	204	48	136	204
	Single fiber fineness	dtex	9.8	9.8	9.8	9.8	4.8	9.8	1.7	6.9
	Dry tenacity	N	47.3	47.0	46.0	44.9	91.4	45.8	21.8	130
	Dry strength	cN/dtex	10.1	10.0	9.8	9.6	9.4	9.7	9.3	9.3
	Dry elongation	%	17.8	17.3	17.4	18.1	21.3	18.1	20.6	19.0
	Dry intermediate elongation	%	9.8	9.9	10.0	10.3	10.8	10.1	9.5	10.9
	Wet tenacity	N	47.0	46.2	44.6	44.7	89.4	44.0	21.1	126.4
	Wet strength	cN/dtex	10.0	9.8	9.5	9.5	9.2	9.4	9.0	9.0
	Wet elongation	%	18.2	17.3	17.5	18.5	22.0	18.4	21.5	19.5
	Wet intermediate elongation	%	10.2	10.3	10.3	10.7	11.0	10.2	9.9	11.4
	Wet strength change rate	%	0.6	1.7	3.0	0.4	2.2	3.9	3.2	2.8
	Wet elongation change rate	%	2.2	0.0	0.6	2.2	3.3	1.7	4.4	2.6
	Wet intermediate elongation change rate	%	4.1	4.0	3.0	3.9	1.9	1.0	4.2	4.6
	Birefringence $\Delta n (\times 10^{-3})$	-	58.2	55.2	52.3	53.8	51.6	52.0	54.2	51.3

[Table 2]

Form	Item	Unit	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4
Chip	Type of polymer	-	N610	N610	N610	N6
	Sulfuric acid relative viscosity	-	3.82	3.82	4.00	3.80
	Moisture content	%	0.05	0.02	0.02	0.05
Multifilament	Sulfuric acid relative viscosity	-	3.63	3.74	3.90	3.90
	Total fineness	dtex	470	470	470	2100
	Number of filaments	-	48	48	48	306
	Single fiber fineness	dtex	9.8	9.8	9.8	6.9
	Dry tenacity	N	41.3	41.7	39.0	193
	Dry strength	cN/dtex	8.8	8.9	8.3	9.2
	Dry elongation	%	20.0	20.0	19.0	20.0
	Dry intermediate elongation	%	10.0	10.1	9.8	10.2
	Wet tenacity	N	41.2	40.9	38.9	167.4
	Wet strength	cN/dtex	8.8	8.7	8.3	8.0
	Wet elongation	%	20.8	21.2	19.4	22.4
	Wet intermediate elongation	%	10.3	10.5	9.9	11.3
	Wet strength change rate	%	0.2	1.9	0.3	13.4
	Wet elongation change rate	%	4.0	6.0	2.1	12.0
	Wet intermediate elongation change rate	%	3.0	4.0	1.0	10.8
	Birefringence Δn ($\times 10^{-3}$)	-	47.0	47.2	46.3	48.2

DESCRIPTION OF REFERENCE SIGNS

[0091]

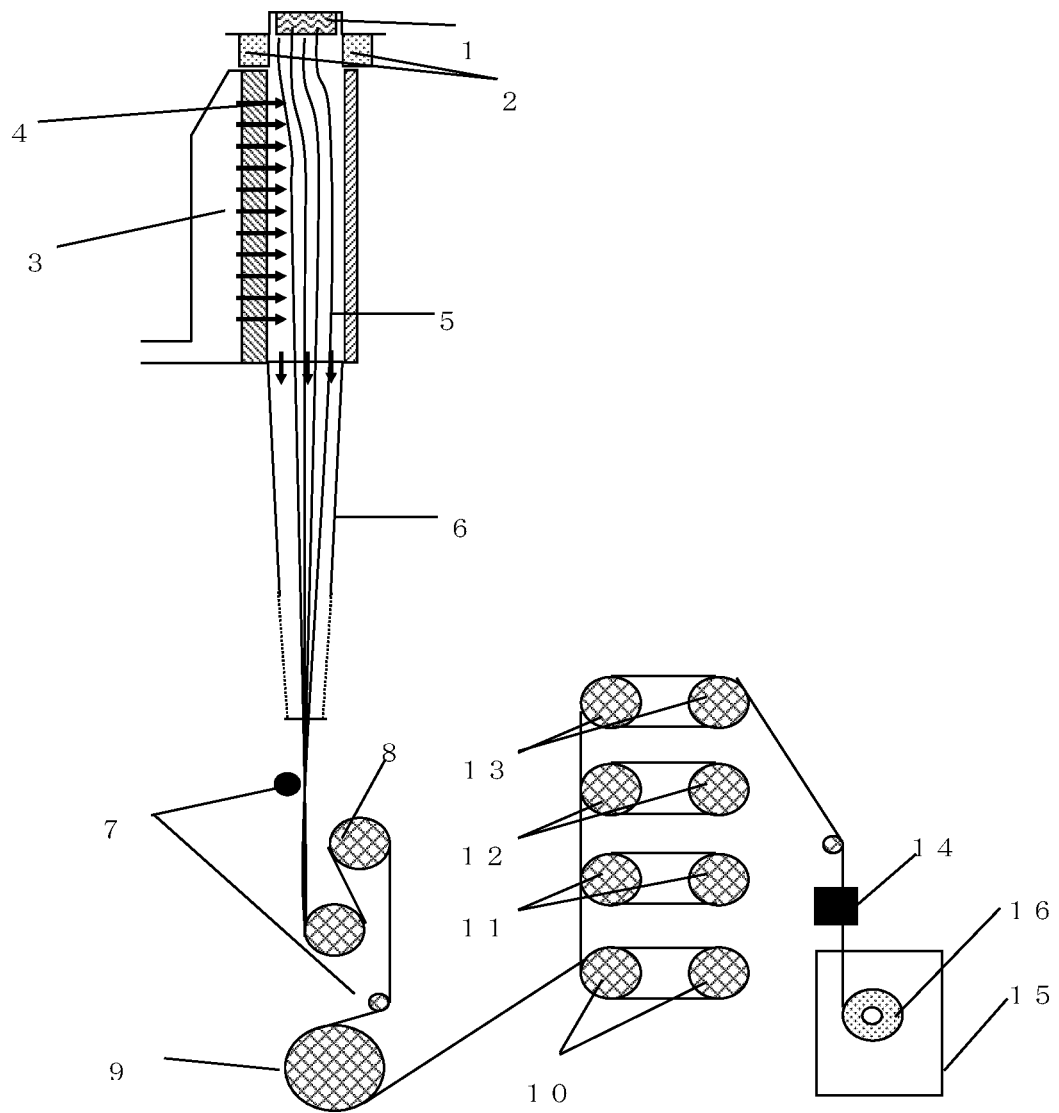
- 1: Spinneret
- 2: Heating cylinder
- 3: Crossflow cooling device
- 4: Cooling air
- 5: Yarn
- 6: Duct
- 7: Oiling device

- 8: Take-up roller
- 9: Take-up roller
- 10: First drawing roller
- 11: Second drawing roller
- 12: Third drawing roller
- 13: Relaxation roller
- 14: Entangling device
- 15: Winder
- 16: Fiber package

Claims

1. A high-strength polyamide 610 multifilament having a sulfuric acid relative viscosity of 3.0 to 3.7 and a dry strength of more than 9.2 cN/dtex and 11.0 cN/dtex or less.
2. The high-strength polyamide 610 multifilament according to claim 1, having a total fineness of 100 to 2,500 dtex and a single fiber fineness of 1.5 to 40 dtex.
3. The high-strength polyamide 610 multifilament according to claim 1 or 2, having a birefringence Δn of 50.0×10^{-3} or more.
4. The high-strength polyamide 610 multifilament according to any one of claims 1 to 3, having a sulfuric acid relative viscosity of 3.0 to 3.3 and a dry strength of more than 9.2 cN/dtex and 11.0 cN/dtex or less.
5. The high-strength polyamide 610 multifilament according to any one of claims 1 to 4, having change rates of strength, elongation, and intermediate elongation in a wet state of all 10% or less.
6. A rope comprising the high-strength polyamide 610 multifilament according to any one of claims 1 to 5.
7. A racket string comprising the high-strength polyamide 610 multifilament according to any one of claims 1 to 5.
8. A textile for a bag fabric, comprising the high-strength polyamide 610 multifilament according to any one of claims 1 to 5.
9. A fishing net comprising the high-strength polyamide 610 multifilament according to any one of claims 1 to 5.

Figure 1



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/009465

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. D01F6/60 (2006.01) i, A63B51/02 (2015.01) i, D07B1/02 (2006.01) i
 FI: D01F6/60351C, D07B1/02, A63B51/02

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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)

Int.Cl. D01F1/00-6/96, 9/00-9/04, A63B51/02, D07B1/00-13/02, D02J1/00-13/00

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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

20

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 JSTPlus/JST7580 (JDreamIII)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

25

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2019/163971 A1 (TORAY INDUSTRIES, INC.) 29 August 2019 (2019-08-29), claims, paragraphs [0002], [0009]-[0019], fig. 1	1-9
Y	JP 2012-251263 A (TORAY INDUSTRIES, INC.) 20 December 2012 (2012-12-20), claim 1, paragraphs [0014], [0016]-[0050]	1-9
Y	JP 60-119215 A (UNITIKA LTD.) 26 June 1985 (1985-06-26), claims, page 1, right column, lines 6-10, page 3, upper right column, line 6 to lower left column, line 3	3
P, X	JP 2020-133061 A (TORAY INDUSTRIES, INC.) 31 August 2020 (2020-08-31), claims, paragraphs [0001], [0016]-[0037]	1-2, 4-9

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

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* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

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Date of the actual completion of the international search
 24 May 2021

Date of mailing of the international search report
 01 June 2021

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Name and mailing address of the ISA/
 Japan Patent Office
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 Tokyo 100-8915, Japan

Authorized officer

 Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No. PCT/JP2021/009465
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WO 2019/163971 A1	29 August 2019	TW 201937022 A
JP 2012-251263 A	20 December 2012	(Family: none)
JP 60-119215 A	26 June 1985	(Family: none)
JP 2020-133061 A	31 August 2020	(Family: none)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2011001635 A [0007]
- JP 2014214405 A [0007]
- WO 2019163971 A [0007]