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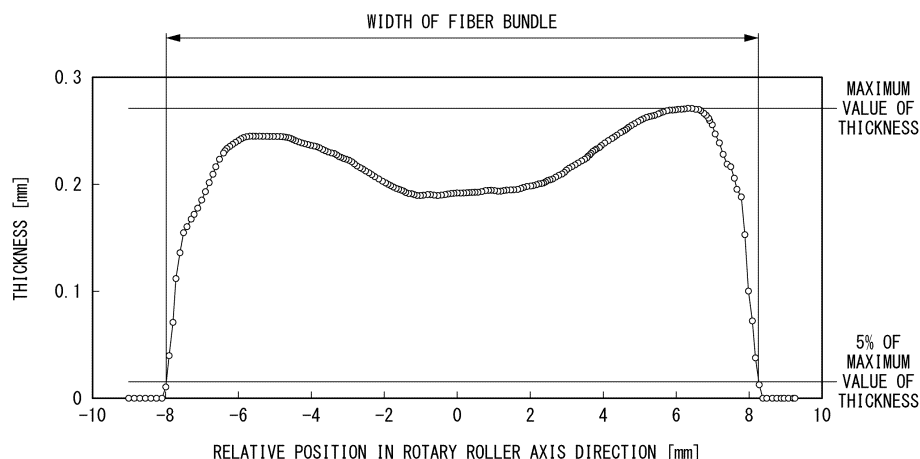
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(54) **CARBON FIBER BUNDLE**

(57) A carbon fiber bundle having a total fineness of 2 g/m or more and a variation rate of a thickness of the fiber bundle of 30% or less in a width direction of the fiber bundle. A manufacturing method of a carbon fiber bundle comprising applying a sizing agent to the carbonized fiber bundle, drying the carbonized fiber bundle, then passing

the carbonized fiber bundle such that one surface of the carbonized fiber bundle in the width direction and one opposite surface thereof are alternately brought into contact with two or more parallel rods, and winding the carbonized fiber bundle on a bobbin.

FIG. 1



Description

[Technical Field]

[0001] The present invention relates to a carbon fiber bundle capable of obtaining molded products which has a good handling during high-order processing and which has carbon fibers uniformly distributed, even when the carbon fiber bundle has a large total fineness.

[0002] Priority is claimed on Japanese Patent Application No. 2021-052932, filed March 26, 2021, the content of which is incorporated herein by reference.

[Background Art]

[0003] Since carbon fibers are excellent in specific strength and specific elastic modulus, carbon fibers are widely used from sports and leisure goods to aerospace applications. In addition to sports applications such as golf club shafts and fishing rods and aircraft applications, the development to so-called general industrial applications such as windmill members for power generation, automobile members, CNG tanks, seismic reinforcement of structures, and ship members is progressed, and a carbon fiber bundle having a large mass per unit length (total fineness) is required.

[0004] When a carbon fiber bundle having a large total fineness is processed into a prepreg by a drum winding method or when various composite materials are molded by a filament winding method or the like, a resin is applied to the carbon fiber bundle by a touch roll method. However, according to the conventional technique, the parts with a high fiber content and the parts with a low fiber content are partially present in the molded article, and the parts with the low fiber content may be the starting point of early fracture.

[0005] One of the causes is considered to be thickness unevenness in the width direction of the carbon fiber bundle having a large total fineness. The width of the carbon fiber bundle having a large total fineness has to be regulated by a width regulating guide or the like to prevent adjacent fiber bundles that is undergoing processing from being in contact with each other and entangled or stuck to each other in a sintering step, a sizing agent applying step, or the like during the production step of the carbon fiber precursor fiber bundle. When passing through the width regulating guide, the fiber bundle is in a state of being pressed from both sides, and thickness unevenness is likely to occur.

[0006] In addition, when the carbon fiber bundle is wound, the width is narrowed by a concavely curved guide, therefore thickness unevenness is likely to occur.

[0007] Patent Document 1 discloses a method for manufacturing a carbon fiber bundle having a wide width and large total fineness in which the variation rate of the yarn width is small and the yarn width is uniform during unwinding, when winding 60,000 carbon fiber bundles, by twisting the fiber bundle 90 degrees at a traverse place, twisting back again, and winding around with a concavely curved guide.

[0008] Patent Document 2 discloses a method for reducing the variation of yarn width by a guide that stabilizes a yarn path when winding 36,000 carbon fiber bundles.

[0009] Patent Document 3 discloses a carbon fiber bundle obtained by impregnating 24,000 fiber bundles with a sizing agent after sintering and being in contact with a heat roller having a surface temperature of 120°C to 140°C for 15 to 30 seconds such that oblateness (ratio between width and thickness of carbon fiber bundle) of the cross section of the fiber bundle is 40 to 90 and a drape value (softness of the carbon fiber bundle) is 50 to 100 mm.

[Citation List]

[Patent Documents]

[0010]

[Patent Document 1]

Japanese Unexamined Patent Application, First Publication No. 2011-11830

[Patent Document 2]

Japanese Unexamined Patent Application, First Publication No. 2012-154000

[Patent Document 3]

Japanese Unexamined Patent Application, First Publication No. 2011-252264

[Summary of Invention]

[Technical Problem]

[0011] However, in Patent Document 1, the variation rate of the thickness is large as shown in Comparative Example of the present application.

[0012] In Patent Documents 2 and 3, the variation rate of the thickness of the carbon fiber bundle is not described and is not controlled.

[0013] In the sizing agent applying step, the carbon fiber bundle is passed through the comb guide, dried and wound while the variation rate of the thickness is kept large, so that the variation rate of the thickness is still large.

[0014] The objective of the present invention is to provide a carbon fiber bundle capable of solving the conventional issues and obtaining molded products which has a good handling during high-order processing, which has carbon fibers uniformly distributed, and which has uniform fiber content, even when the carbon fiber bundle has a large total fineness.

[Solution to Problem]

[0015] The carbon fiber bundle according to the present invention has the following characteristics.

[1] A carbon fiber bundle having a total fineness of 2 g/m or more and a variation rate of a thickness of the fiber bundle in a width direction of the fiber bundle of 30% or less.

[2] The carbon fiber bundle according to [1], wherein the number of single fibers is 20,000 or more.

[3] The carbon fiber bundle according to [1] or [2], wherein the fiber bundle has an average thickness of 0.18 to 0.28 mm.

[4] The carbon fiber bundle according to any one of [1] to [3], wherein the fiber bundle has a variation rate of a width in a length direction of the fiber bundle of 13% or less.

[5] The carbon fiber bundle according to any of [1] to [4], wherein the fiber bundle has a width of 13 to 18 mm.

[6] The carbon fiber bundle according to any of [1] to [5], wherein the fiber bundle has a flatness (width/average thickness) of 60 to 70.

[7] The carbon fiber bundle according to any one of [1] to [6], wherein a cantilever value is 210 to 250 mm and a stickability is 0.18 m or less.

[8] The carbon fiber bundle according to any of [1] to [7], wherein an adhesion amount of a sizing agent is 0% to 20% by mass.

[9] The carbon fiber bundle according to any of [1] to [8], wherein a fiber-fiber dynamic friction coefficient is 0.2 or less.

[10] The carbon fiber bundle according to any of [1] to [9], wherein a fiber-metal dynamic friction coefficient is 0.18 or less.

[11] A manufacturing method of a carbon fiber bundle, comprising in an averaging member having two or more parallel rods arranged between a sizing agent dryer and a winder or a transfer device, passing a carbonized fiber bundle through the averaging member such that each of a surface A of the carbonized fiber bundle and a surface B of the carbonized fiber bundle opposite side to the surface A comes into contact with the rods at least once or more.

[12] The manufacturing method of a carbon fiber bundle according to [11], wherein a distance between adjacent rods of the parallel rods is 15 to 50 mm.

[13] The manufacturing method of a carbon fiber bundle according to [11] or [12], wherein in the passing the carbonized fiber bundle, the carbonized fiber bundle is passed such that the carbonized fiber bundle is brought into contact with the parallel rods in a state where a surface direction of a carbon fiber bundle in contact with a roller one before the parallel rods is twisted by 90°.

[14] The manufacturing method of a carbon fiber bundle according to any of [11] to [13], wherein in the passing the carbonized fiber bundle, the carbonized fiber bundle is passed such that a maximum width of the carbonized fiber bundle in contact with the parallel rods is 5% to 20% wide with respect to a width of a carbonized fiber bundle in contact with a roller one before the parallel rods.

[15] The manufacturing method according to [13] or [14], wherein the roller is located upstream of the parallel rods in a traveling direction of the carbonized fiber bundle, and a length direction of the roller and a length direction of the parallel rods are substantially perpendicular to each other.

[16] The manufacturing method according to any of [13] to [15], wherein a distance from a center of the roller to a center of the parallel rods is preferably 200 to 1,500 mm and more preferably 500 to 1,000 mm at a position where the distance is shortest.

[17] The manufacturing method of a carbon fiber bundle according to any of [11] to [16], wherein in the passing the carbonized fiber bundle, the carbonized fiber bundle is flat, and the carbonized fiber bundle is passed through the averaging member such that one surface A of the carbonized fiber bundle is brought into contact with the parallel

rods located upstream in a traveling direction of the carbonized fiber bundle and then the other surface B of the carbonized fiber bundle is brought into contact with the parallel rods located downstream in the traveling direction of the carbonized fiber bundle.

[18] The manufacturing method of a carbon fiber bundle according to any of [11] to [17], the manufacturing method comprising before the passing the carbonized fiber bundle, changing a direction of a surface of the carbonized fiber bundle with a length direction of the carbonized fiber bundle as an axis.

[19] The manufacturing method according to [18], wherein in changing the direction of the surface, the surface of the carbonized fiber bundle is preferably tilted in a width direction within a range of 30° to 150° with the length direction of the carbonized fiber bundle as the axis, the surface of the carbonized fiber bundle is more preferably tilted in the width direction within a range of 45° to 135° with the length direction of the carbonized fiber bundle as the axis, the surface of the carbonized fiber bundle is even more preferably tilted in the width direction within a range of 60° to 120° with the length direction of the carbonized fiber bundle as the axis, and the surface of the carbonized fiber bundle is particularly preferably tilted in the width direction by 90° with the length direction of the carbonized fiber bundle as the axis.

[20] The manufacturing method according to [18] or [19], wherein the changing the direction of the surface is performed between a roller located upstream of the two or more parallel rods in the traveling direction of the carbonized fiber bundle, and the parallel rods located most upstream among the two or more parallel rods.

[21] The manufacturing method according to any of [11] to [20], which is a manufacturing method of the carbon fiber bundle according to any of [1] to [10].

[0016] The carbon fiber bundle according to the present invention also has the following characteristics.

[1a] A manufacturing method of carbon fiber bundle, comprising bringing one surface A of the carbonized fiber bundle into contact with a first rod and bringing the other surface B of the carbonized fiber bundle into contact with a second rod.

[2a] The manufacturing method according to [1a], comprising changing a direction of a surface of the carbonized fiber bundle with a length direction of the carbonized fiber bundle as an axis.

[3a] The manufacturing method according to [2a], wherein in changing the direction of the surface, the surface of the carbonized fiber bundle is preferably tilted in a width direction within a range of 30° to 150° with the length direction of the carbonized fiber bundle as the axis, the surface of the carbonized fiber bundle is more preferably tilted in the width direction within a range of 45° to 135° with the length direction of the carbonized fiber bundle as the axis, the surface of the carbonized fiber bundle is even more preferably tilted in the width direction within a range of 60° to 120° with the length direction of the carbonized fiber bundle as the axis, and the surface of the carbonized fiber bundle is particularly preferably tilted in the width direction by 90° with the length direction of the carbonized fiber bundle as the axis.

[4a] The manufacturing method according to [2a] or [3a], wherein the changing the direction of the surface, the bringing the surface A into contact with the first rod, and the bringing the surface B into contact with the second rod are performed in this order.

[5a] The manufacturing method according to any of [2a] to [4a], wherein by performing the changing the direction of the surface, the bringing the surface A into contact with the first rod, and the bringing the surface B into contact with the second rod, in this order, a width of the carbon fiber bundle after performing these steps is widened to be in a range of 105% to 120% with respect to 100% of a width of the carbon fiber bundle before performing these steps.

[6a] The manufacturing method according to any of [1a] to [5a], which is a manufacturing method of the carbon fiber bundle according to any of [1] to [10].

[Advantageous Effects of Invention]

[0017] The carbon fiber bundle of the present invention is capable of obtaining molded products which has a good handling during high-order processing and which has carbon fibers uniformly distributed, even when the carbon fiber bundle has a large total fineness.

[Brief Description of Drawings]

[0018]

FIG. 1 is a diagram showing a method of calculating a variation rate of a thickness of a carbon fiber bundle.

FIG. 2 is a diagram showing an example of an apparatus used for measuring a fiber-fiber dynamic friction coefficient and a fiber-metal dynamic friction coefficient of a carbon fiber bundle.

FIG. 3 is a diagram showing an example of an averaging member used for manufacturing the carbon fiber bundle of the present invention.

FIG. 4 is a perspective view showing an example of a state in which the carbonized fiber bundle of the present invention passes through parallel rods.

FIG. 5 is a top view showing an example of the state in which the carbonized fiber bundle of the present invention passes through the parallel rods.

FIG. 6 is a diagram showing an example of an arrangement place of an averaging member of the present invention.

FIG. 7 is a diagram showing an example of a winder of the present invention.

[Description of Embodiments]

[0019] The carbon fiber bundle of the present invention is a carbon fiber bundle having a total fineness of 2 g/m or more and a variation rate of a thickness of the fiber bundle in a width direction of the fiber bundle of 30% or less.

[0020] The carbon fiber bundle of the present invention is a carbon fiber bundle having a total fineness of 2.0 g/m or more. Since the productivity of the carbon fiber bundle depends on the total fineness of the carbon fiber bundle, the carbon fiber bundle can be efficiently manufactured in a case where the mass per unit length of the carbon fiber bundle is large. The total fineness is more preferably 2.5 g/m or more and most preferably 3 g/m or more.

[0021] The total fineness of 2.0 g/m expressed as dtex is 20,000 dtex.

[0022] The variation rate of the thickness of the carbon fiber bundle in the width direction of the fiber bundle of the present invention (hereinafter, "the variation rate of the thickness of the carbon fiber bundle in the width direction of the fiber bundle" may be simply referred to as "the variation rate of the thickness") can be measured by the method described later.

[0023] In the carbon fiber bundle of the present invention, the variation rate of the thickness of the carbon fiber bundle is preferably 30% or less. By setting the variation rate of the thickness of the carbon fiber bundle to 30% or less, it is possible to produce a molded product in which carbon fibers are uniformly distributed. The variation rate of the thickness of the carbon fiber bundle is more preferably 20% or less and even more preferably 15% or less.

[0024] In the carbon fiber bundle of the present invention, the number of single fibers is preferably 20,000 or more.

[0025] As the number of single fibers increases, the productivity increases, which is preferable. In addition, the variation rate of thickness increases as the number of single fibers increases, and therefore the manufacturing method of a carbon fiber bundle of the present invention can be easily applied. From these viewpoints, the number of single fibers is more preferably 30,000 or more and even more preferably 40,000 or more.

[0026] In the carbon fiber bundle of the present invention, an average thickness of the fiber bundle is preferably 0.18 to 0.28 mm.

[0027] In a case where the average thickness of the fiber bundle is 0.18 mm or more, the width of the carbon fiber bundle having a large total fineness does not excessively increase and handleability is likely to be improved. In a case where the average thickness of the fiber bundle is 0.28 mm or less, the variation rate of the thickness is likely to be reduced.

[0028] From these viewpoints, the average thickness of the fiber bundle is more preferably 0.20 to 0.27 mm and even more preferably 0.21 to 0.25 mm.

[0029] In the carbon fiber bundle of the present invention, the variation rate of the width of the fiber bundle in the length direction of the fiber bundle is preferably 13% or less. In a case where the variation rate of the width of the fiber bundle is 13% or less, a molded product in which carbon fibers are uniformly distributed is likely to be produced. The variation rate of the thickness of the carbon fiber bundle is more preferably 12% or less and even more preferably 11% or less.

[0030] The variation rate of the width of the carbon fiber bundle in the length direction of the fiber bundle of the present invention can be measured by a method described later.

(Measurement method of average value of thicknesses of carbon fiber bundle, variation rate of thickness and width of carbon fibers, variation rate of width)

[0031] The measurement is performed in an environment where the room temperature is 25°C and the humidity is 50%. The carbon fiber bundle is brought into contact with a free rotating roller having a diameter of 60 mm with a wrap angle of $\theta = \pi$ (rad) in a state where a tension of 0.40 cN/tex is applied to the carbon fiber bundle, a two-dimensional line laser displacement sensor is installed on the intermediate point of the wrap angle of the rotating roller, and displacement data is acquired at a ratio of 10 m/min simultaneously in a line at an equal interval of 0.1 mm in the width direction of the carbon fiber bundle. Excluding the measurement points in a region where the displacement is 5% or less of the maximum value at both ends of the line of displacement data among the line of data, the average value and the standard deviation of the displacement are calculated (FIG. 1) and the variation rate is calculated from the ratio of both of them. The average value of the displacement is referred to as an average value of the thicknesses. At this time, the width of the range for calculating the average value and the standard deviation of the thicknesses is recorded as the width of the

fiber bundle. The average value of the variation rate of each point obtained by measuring 300 points at intervals of 2 cm in the longitudinal direction of the carbon fiber bundle is referred to as "the variation rate of the thickness in the width direction of the carbon fiber bundle" of the carbon fiber bundle to be measured. In addition, an average value and a standard deviation of the 300 points of widths of the fiber bundle which are simultaneously obtained are calculated, the ratio of both of them is referred to as "the variation rate of the width in the length direction of the carbon fiber bundle" of the carbon fiber bundle to be measured, the average value of the widths of the fiber bundle is referred to as the width of the carbon fibers.

[0032] In the carbon fiber bundle of the present invention, a width of the carbon fiber bundle is preferably 13 to 18 mm.

[0033] In a case where the width of the carbon fibers is 13 mm or more, the thickness of the fiber bundle does not excessively increase and the variation rate of the thickness is likely to be reduced. In a case where the width of the carbon fibers is 18 mm or less, the fiber bundle is not broken and handling is likely to become easy.

[0034] From these viewpoints, the width of the carbon fiber bundle is more preferably 13.5 to 16.5 mm and even more preferably 14 to 17 mm.

[0035] In the carbon fiber bundle of the present invention, the flatness (width/average thickness) of the carbon fiber bundle is preferably 60 to 70.

[0036] In a case where the flatness of the carbon fiber bundle is 60 or more, the thickness of the carbon fiber bundle does not excessively increase. In a case where the flatness of the carbon fiber bundle is 70 or less, the width does not excessively increase and handleability is likely to be improved.

[0037] From these viewpoints, the flatness is more preferably 61 to 69 and even more preferably 62 to 68.

[0038] In the carbon fiber bundle of the present invention, a cantilever value is preferably 210 to 250 mm.

[0039] In a case where the cantilever value is 210 mm or more, it is possible to secure the convergence of the carbon fiber bundle traveling on the yarn path during high-order processing and to prevent the generation of fluff in the yarn path leading to the resin impregnation step from the creel accommodating the carbon fiber bundle when impregnating the carbon fiber bundle with the resin. In a case where the cantilever value is 250 mm or less, favorable openability between the carbon fiber filaments can be secured during high-order processing. The cantilever value is more preferably 220 mm or more and 240 mm or less.

[0040] The cantilever value of the carbon fiber bundle can be measured by a method described later.

(Measurement method of cantilever value of carbon fiber bundle)

[0041] The measurement is performed in an environment where the room temperature is 25°C and the humidity is 50%. About 1 m of the carbon fiber bundle is unwound from the carbon fiber bundle package without applying tension and cut out. In order to remove the influence of the curling of the cut out carbon fiber bundle, one end of the carbon fiber bundle is fixed, a weight of 13 mg/tex is attached to the other end, the carbon fiber bundle is held in a state of being suspended in the vertical direction for 30 minutes, then the weight is removed, and 30 cm of the carbon fiber bundle is cut out such that the end portion is not included to obtain a carbon fiber bundle for test. In a measuring table having a horizontal plane and a slope with a tilt angle of 45 degrees that is tilted downward from one end (a linear shape) of the horizontal plane, the carbon fiber bundle for test is placed in a state where the carbon fiber bundle for test is not twisted and is not disordered on the horizontal plane and an end portion (a linear shape) of the carbon fiber bundle for test is aligned with a boundary line between the slope and the horizontal plane. A metal pressing plate is placed on the carbon fiber bundle for test, and an end portion (a linear shape) of the pressing plate is aligned with the boundary line. Next, the pressing plate is moved in the horizontal direction toward the slope at a speed of 0.5 cm/sec, the movement of the pressing plate is stopped at the time when the end portion of the carbon fiber bundle for test comes into contact with the slope, and the shortest distance between the boundary line and the time point where the end portion of the carbon fiber bundle comes into contact with the slope is measured. The measurement is performed once for each of the five carbon fiber bundles for test, and a simple average value of the obtained values is used as the cantilever value of the carbon fiber bundle.

[0042] In the carbon fiber bundle of the present invention, a stickability is preferably 0.18 m or less.

[0043] In a case where the stickability is 0.18 m or less, it is possible to secure the convergence of the carbon fiber bundle traveling on the yarn path during high-order processing and to prevent the generation of fluff in the yarn path leading to the resin impregnation step from the creel accommodating the carbon fiber bundle when impregnating the carbon fiber bundle with the matrix resin. The stickability is more preferably 0.16 m or less.

[0044] The stickability of the carbon fiber bundle can be measured by a method described later.

(Measurement method of stickability of carbon fiber bundle)

[0045] The measurement is performed in an environment where the room temperature is 25°C, the humidity is 50%, and there is no wind. While a spool having a diameter of 20 to 25 cm in which the carbon fiber bundle is wound, is held

such that the axial direction thereof is horizontal, the carbon fiber bundle is unwound without applying tension, and the carbon fiber bundle is cut at a position which is 10 cm lower than the height of the center of the shaft of the spool. Next, the spool is vertically erected such that from the contact start point between the fiber bundle unwound by the unwinding of the carbon fiber bundle and the spool, the direction in which the carbon fiber bundle is obliquely wound on the spool is a direction in which the spool is moved vertically. The spool is held without applying vibration. After holding for 10 minutes, the carbon fiber bundle is cut off at a position 10 cm from the contact start point with the spool, and the length of the carbon fiber bundle peeled off from the spool is measured. The measurement is carried out three times, and a simple average value of the obtained values is used as a measured value of the stickability of the carbon fiber bundle.

[0046] In the carbon fiber bundle of the present invention, an adhesion amount of the sizing agent is preferably 0% to 20% by mass.

[0047] In a case where the adhesion amount of the sizing agent is 20% by mass or less, the fiber bundles do not easily adhere to each other, and thus the variation rate of the thickness can be easily reduced.

[0048] From this viewpoint, the adhesion amount of the sizing agent is more preferably 15% by mass or less, even more preferably 10% by mass or less, and most preferably 5% by mass or less.

[0049] The lower limit value is preferably 0% by mass from the viewpoint of thickness unevenness, but from the viewpoint that the carbon fiber bundles are bundled to improve handleability, the adhesion amount of the sizing agent is more preferably 0.5% by mass or more and even more preferably 1% by mass or more.

[0050] In the carbon fiber bundle of the present invention, a fiber-fiber dynamic friction coefficient is preferably 0.2 or less.

[0051] In a case where the fiber-fiber dynamic friction coefficient is 0.2 or less, the frictional force between a single yarn is reduced. Therefore, the generation of fluff due to abrasion between the carbon fiber filaments is suppressed, and a phenomenon called a ringer in which fluff surrounds the bobbin to prevent the carbon fiber bundle from being unwound. The fiber-fiber dynamic friction coefficient is more preferably 0.17 or less.

[0052] The fiber-fiber dynamic friction coefficient can be measured by a method described later.

(Measurement method of fiber-fiber dynamic friction coefficient)

[0053] An example of the measuring apparatus is shown in FIG. 2. The carbon fiber bundle 2 to be measured is wound and fixed without a gap on a drive roller 1 having a heating device and having a diameter of 30 mm with a lead angle in a range of 0.1 to 0.5 mm in thickness such that the thickness is uniform. In a state where the drive roller 1 is stopped, the carbon fiber bundle 2 to be measured is disposed in a yarn path shown in FIG. 2 such that a wrap angle $\theta = \pi$ (rad). The surface temperature of the drive roller 1 is 30°C. A weight 4 (T1 = 0.53 g/tex) is attached to one end portion of the carbon fiber bundle 2 disposed in the yarn path, and a spring scale 5 is attached to the opposite end. The drive roller 1 is rotated at a rotation speed of 60 rpm, and one minute later, the center value T2 (g) of the indicated value of the spring scale 5 is read. The measurement is carried out twice, and the fiber-fiber dynamic friction coefficient is calculated from the average value of the obtained T2.

Fiber-fiber dynamic friction coefficient = $\pi^{-1} \ln((\text{average value of T2}) / (T1 \times \text{total fineness}))$

[0054] In the carbon fiber bundle of the present invention, a fiber-metal dynamic friction coefficient is preferably 0.18 or less.

[0055] In a case where the fiber-metal dynamic friction coefficient is 0.18 or less, the frictional force between the metal guide and the carbon fiber filament is reduced, and thus the abrasion resistance is improved. The fiber-metal dynamic friction coefficient is more preferably 0.16 or less.

[0056] The fiber-metal dynamic friction coefficient can be measured by a method described later.

(Measurement method of fiber-metal dynamic friction coefficient)

[0057] An example of the measuring apparatus is shown in FIG. 2. In a state where the drive roller 1 having a heating device and having a diameter of 30 mm is stopped, the carbon fiber bundle 2 to be measured is disposed in a yarn path shown in FIG. 2 such that a wrap angle $\theta = \pi$ (rad). Unlike the measurement method of the fiber-fiber dynamic friction coefficient described above, in the measurement method of the fiber-metal dynamic friction coefficient, the carbon fiber bundle 2 to be measured is only hung on the drive roller 1 and the carbon fiber bundle 2 is not wound. The drive roller 1 is a metal roller (Material: S45C-H, satin finish processing of mesh 400), and the surface temperature is 30°C. A weight 4 (T3 = 0.53 g/tex) is attached to one end portion of the carbon fiber bundle 2 disposed in the yarn path, and a spring scale 5 is attached to the opposite end. The drive roller 1 is rotated at a rotation speed of 60 rpm, and five minutes later, the center value T4 (g) of the indicated value of the spring scale 5 is read. The measurement is carried out twice, and the fiber-metal dynamic friction coefficient is calculated from the average value of the obtained T4.

Fiber-metal dynamic friction coefficient = $\pi^{-1} \ln((\text{average value of } T_4)/(T_3 \times \text{total fineness}))$

(Manufacturing method of carbon fiber bundle)

[0058] The manufacturing method of a carbon fiber bundle of the present invention is not particularly limited, and for example, the carbon fiber bundle can be manufactured by a method including the following steps (a) to (i).

- (a) A step of spinning and coagulating a spinning dope to obtain a coagulated yarn.
- (b) A step of washing and drawing the coagulated yarn to obtain a precursor yarn that is undergoing processing.
- (c) A step of adhering an oil to the precursor yarn that is undergoing processing and drying and densifying it to obtain a precursor fiber bundle.
- (d) A step of subjecting the precursor fiber bundle to flame-resistant treatment to obtain a flame-resistant fiber bundle.
- (e) A step of subjecting the flame-resistant fiber bundle to carbonization treatment to obtain a carbonized fiber bundle.
- (f) A step of subjecting the carbonized fiber bundle to surface oxidation treatment.
- (g) A step of applying a sizing agent to the carbonized fiber bundle after surface oxidation treatment.
- (h) A step of homogenizing the carbonized fiber bundle after applying the sizing agent.
- (i) A winding step of winding the carbonized fiber bundle on a bobbin to obtain a carbon fiber bundle.

[0059] FIG. 6 and FIG. 7 show a general process chart of a step transition of applying the sizing agent for the carbonized fiber bundle, and the averaging member of the present invention is arranged at the part of the broken line indicated by A in FIG. 6.

[0060] In the step (a), a spinning dope is spun and coagulated to obtain a coagulated yarn.

[0061] The spinning dope used in the step (a) is not particularly limited. From the viewpoint of expressing mechanical properties such as the strength of the carbon fibers, an organic solvent solution of the acrylonitrile copolymer is preferable. The acrylonitrile copolymer is a copolymer having 90% by mass or more of a repeating unit derived from acrylonitrile, and is preferably a copolymer having 95% by mass or more of a repeating unit derived from acrylonitrile.

[0062] In the acrylonitrile copolymer, examples of a repeating unit (hereinafter, referred to as "copolymerization component") derived from other than acrylonitrile include acrylic acid derivatives such as acrylic acid, methacrylic acid, itaconic acid, and methyl acrylate, methacrylic acid derivatives such as methyl methacrylate, acrylamide derivatives such as acrylamide, methacrylamide, N-methylolacrylamide, N,N-dimethylacrylamide, and vinyl monomers such as vinyl acetate. The copolymerization component may be one kind or two or more kinds thereof. As the copolymerization component, a vinyl monomer having one or more carboxy groups is preferable.

[0063] The polymerization method for manufacturing the acrylonitrile copolymer is not particularly limited, and examples thereof include solution polymerization in an organic solvent for dissolving the acrylonitrile copolymer, precipitation polymerization in water, and the like.

[0064] Examples of the organic solvent used for the spinning dope include polar organic solvents such as dimethylacetamide, dimethylsulfoxide, and dimethylformamide. Since the spinning dope obtained by using these polar organic solvents does not contain a metal element, the content of the metal element in the carbon fiber bundle to be obtained can be reduced. The solid content concentration of the spinning dope is preferably 20% by mass or more.

[0065] The spinning method may be any of wet spinning and dry-wet spinning. For example, in wet spinning, a large number of filaments formed by spinning the spinning dope from a spinneret in which a large number of discharge holes are disposed into a coagulation liquid at a temperature controlled and coagulating, are bundled and collected as a coagulated yarn. As the coagulation liquid, a known coagulation liquid such as a mixed solution of water and a polar organic solvent used for the spinning dope can be used.

[0066] In the step (b), the coagulated yarn obtained in the step (a) is washed and drawn to obtain a precursor yarn that is undergoing processing. The method for washing may be any method as long as the solvent can be removed from the coagulated yarn, and a known method can be employed. A more dense fibril structure can also be formed by drawing the fibers in the air or in a solvent aqueous solution at high temperature which has a lower solvent concentration than the coagulation liquid before washing the coagulated yarn. In addition, the alignment of the acrylonitrile copolymer in the fibers can be further improved by drawing the fibers in hot water after washing the coagulated yarn.

[0067] In the step (c), an oil is adhered to the precursor yarn that is undergoing processing obtained in the step (b) and the precursor yarn is dried and densified to obtain a precursor fiber bundle. As the oil, known oils can be used, and examples thereof include an oil composed of a silicone-based compound such as silicone oil.

[0068] The method for drying and densifying is not particularly limited as long as the precursor yarn that is undergoing processing to which the oil has been adhered is densified by drying using a known drying method.

[0069] The fibers after drying and densifying, as necessary, may be drawn 1.8 to 6 times in pressure steam at 130°C to 200°C, or between heating rollers or on a heating plate to carry out further improvement of the alignment of the precursor fiber bundle and densification thereof.

[0070] In the step (d), the precursor fiber bundle obtained in the step (c) is subjected to flame-resistant treatment to obtain a flame-resistant fiber bundle.

[0071] Examples of the flame-resistant treatment include a method of allowing the precursor fiber bundle to pass, for 30 to 100 minutes, through a hot air furnace set to increase the temperature in a stepwise manner at 220°C to 260°C. The fibers may be elongated during the flame-resistant treatment. By performing the appropriate elongation in the flame-resistant treatment, the alignment of the fibril structure forming the fibers can be maintained or improved, and a carbon fiber bundle having excellent mechanical properties can be easily obtained. The density of the single fibers constituting the flame-resistant fiber bundle is preferably 1.33 to 1.40 g/cm³.

[0072] In the step (e), the flame-resistant fiber bundle obtained in the step (d) is subjected to carbonization treatment to obtain a carbonized fiber bundle. Examples of the carbonization treatment include a treatment including first carbonization treatment of performing heating treatment in which a maximum temperature is set from 600°C to 800°C in an inert atmosphere such as nitrogen or the like, and second carbonization treatment of performing heating treatment in which a maximum temperature is set from 1,200°C to 2,000°C in an inert atmosphere such as nitrogen or the like.

[0073] The treatment time for the first carbonization treatment is preferably 1 to 3 minutes. In the first carbonization treatment, from the viewpoint of promoting regular alignment of the carbon structure, an elongation operation of 1% to 5% is preferably performed.

[0074] The treatment time in the second carbonization treatment is preferably 1.3 to 5 minutes. The strength and elastic modulus of the carbon fiber bundle can be controlled by the temperature and the treatment time in the second carbonization treatment. In the second carbonization treatment, large shrinkage occurs in the fibers, and thus an elongation ratio is preferably -5% to -2%. After the second carbonization treatment, additional third carbonization treatment may be carried out as necessary.

[0075] In the step (f), the carbonized fiber bundle obtained in the step (e) is subjected to a surface oxidation treatment. A known method can be employed for the surface oxidation treatment, and examples thereof include electrolytic oxidation, chemical oxidation, and air oxidation. Among these, electrolytic oxidation is preferable.

[0076] In the step (g), a sizing agent is applied to the carbonized fiber bundle obtained in the step (f). It is possible to apply the sizing agent to the carbonized fiber bundle by applying a solution in which the sizing agent is dissolved in an organic solvent or an emulsion dispersed in water with an emulsifier or the like to the carbonized fiber bundle and then drying.

[0077] Before and after applying the sizing agent, it is preferable to separate the carbonized fiber bundles adjacent to each other by a comb guide or the like such that the carbonized fiber bundles do not adhere to each other.

[0078] As the sizing agent, an agent having a fiber-fiber dynamic friction coefficient of 0.20 or less and a fiber-metal dynamic friction coefficient of 0.18 or less, which are measured by the method described in the specification, is selected. As long as the sizing agent has a fiber-fiber dynamic friction coefficient of 0.20 or less and a fiber-metal dynamic friction coefficient of 0.18 or less, there is no particular limitation.

[0079] The adhesion amount of the sizing agent to the carbon fiber bundle can be adjusted by adjusting the concentration of the sizing agent in the solution or emulsion or adjusting the throttle amount after applying the solution or emulsion. The adhesion amount of the sizing agent to the carbon fiber bundle is preferably 0.4% to 2.0% with respect to the total mass of the carbon fiber bundle to which the sizing agent is adhered. The drying method after applying the solution or emulsion is not particularly limited, and the drying can be performed using, for example, hot air, a hot plate, a heating roller, an infrared heater, or the like.

[0080] In the step (h), a width of the carbonized fiber bundle is widened to make the thickness of the fiber bundle uniform by using an averaging member for the carbonized fiber bundle until the carbonized fiber bundle obtained in the step (g) is wound.

[0081] It is preferable that the averaging member loosens the fiber bundle such that the single fiber is likely to move, by applying an external force to the fiber bundle to widen the width of the fiber bundle. As the means for applying an external force to the single fiber, friction between the fiber and a metal member, an air flow, vibration, or the like is used, and friction between the fiber and the metal member is preferable because it can be realized with a simple device.

[0082] When manufacturing a large number of carbon fiber bundles, it is preferable to widen the carbon fiber bundles in a direction avoiding contact with adjacent fiber bundles. By the averaging member, a carbon fiber bundle having a favorable cantilever value and favorable stickability is obtained by constantly applying a physical external force to the single fibers constituting the traveling fiber bundle to change a position of the single fiber in the fiber bundle.

[0083] The averaging member used for manufacturing the carbon fiber bundle of the present invention may be any means as long as a physical external force is constantly applied to the single fiber, and it is only necessary to make the distribution uniform by changing the positions of the single fibers constituting the carbonized fiber bundle with each other by a physical external force while avoiding contact between the carbonized fiber bundles traveling adjacent to each other by the averaging member.

[0084] The shape of the averaging member, which applies an external force to the single fiber by friction between the fiber and the metal member, is not particularly limited. As the averaging member, a parallel rod guide, a comb guide, or

the like can be used, and it is preferable to use a parallel rod guide that can efficiently apply an external force to the single fiber and can adjust the external force to be applied. FIG. 3 shows an example of the parallel rod guide. In the parallel rod guide, two straight rods having a smooth surface are preferably held in parallel.

[0085] In the manufacturing method of a carbon fiber bundle of the present invention, in an averaging member having two or more parallel rods arranged between a sizing agent dryer and a traverse guide device or a transfer device, each of a surface A of a carbonized fiber bundle and a surface B of the carbonized fiber bundle opposite side to the surface A comes into contact with the rods at least once or more.

[0086] In this way, the fiber bundle is widened in the width direction, and the adhesion between the single fibers is likely to be loosened.

[0087] The surfaces of the rods that come into contact with the carbonized fiber bundles may be parallel to each other. In addition, the shape of the rod is not particularly limited, such as a circular shape or a square shape. However, in a case where the surface with which the carbonized fiber bundles come into contact has corners, fluffing is likely to be generated, and thus the rod preferably is configured with a curved plane such that the carbonized fiber bundle comes into contact with the plane.

[0088] Since the fiber bundle is loosened by contacting each of the surface A and the surface B with the rod once, the variation rate of the thickness is likely to be reduced.

[0089] From the viewpoint that the fiber bundle is loosened, the rods preferably come into contact with the surface A and the surface B in alternate order of the surface A, the surface B, the surface A, and the surface B as the manner in which the first rod A comes into contact with the surface A, and the second rod comes into contact with the surface B.

[0090] In the manufacturing method of a carbon fiber bundle of the present invention, a distance between adjacent rods of the parallel rods is preferably 15 to 50 mm.

[0091] In a case where the distance between the adjacent rods of the parallel rods is 15 mm or more, the carbonized fiber bundle can be easily passed through, and in a case where the distance thereof is 50 mm or less, the effect of widening the width is likely to be exhibited.

[0092] From these viewpoints, the distance between the adjacent rods of the parallel rods is more preferably 17 to 45 mm and even more preferably 19 to 40 mm.

[0093] In the manufacturing method of a carbon fiber bundle of the present invention, the carbonized fiber bundle is preferably passed such that the carbonized fiber bundle is brought into contact with the parallel rods in a state where a surface direction of a carbon fiber bundle in contact with a roller one before the parallel rods is twisted by 90°.

[0094] By twisting the carbonized fiber bundle by 90°, an external force is applied to the carbonized fiber bundle, and the width of the carbonized fiber bundle is likely to be widen. In addition, when a plurality of carbonized fiber bundles are traveling in parallel, it is preferable because the carbonized fiber bundle does not come into contact with adjacent carbonized fiber bundles and does not take up space.

[0095] In the manufacturing method of a carbon fiber bundle of the present invention, the maximum width of the carbonized fiber bundle in contact with the parallel rods is preferably 5% to 20% wide with respect to the width of the carbonized fiber bundle in contact with the roller one before the parallel rods.

[0096] In addition, the rod is preferably fixed, however in a case where the rod has a resistance such that the surface speed of the rod becomes slower than the speed of the fiber bundle and thus an external force is applied as a frictional force is generated to the rod and the fiber bundle, the rod may rotate.

[0097] In the winding process of the step (i), the carbon fiber bundle is wound on the winding core while being traversed to obtain a spool of the carbon fiber bundle. The method for winding the carbon fiber bundle may be any method as long as the carbon fiber bundle can be wound on the spool in a state where there is no twist or the like. The fiber bundle is narrowed because of the free roll guide 11 having a dent in front of the traverse, but thickness unevenness does not occur by using the averaging member of the present invention.

[0098] In addition, the carbon fiber bundle may be transferred to a packaging box or the like instead of being wound on the spool.

Examples

[0099] Hereinafter, the present invention will be specifically described with reference to examples, but the following examples do not limit the scope of the present invention.

(Measurement method of amount of abrasion fluff)

[0100] The carbon fiber bundle is unwound from the bobbin at a unwinding tension of 0.40 cN/tex and a traveling speed of the carbon fiber bundle of 20 m/min, brought into contact with a fixed metal rod having a diameter of 8 mm (Material: SUS304, chromium-plated-mirror surface treatment) with a wrap angle of 15° via the roller, and abraded. After the carbon fiber bundle has passed 500 m, the traveling thereof is stopped, and fluff deposited on the stainless steel

rod is collected and its mass is measured. The measurement was carried out three times, and a simple average value of the obtained values was used as the amount of abrasion fluff.

[Examples 1 to 10]

(Manufacture of carbon fiber bundle)

[0101] A precursor fiber bundle having a single fiber fineness of 1.33 dtex and the number of a single fiber of 50,000 was subjected to flame-resistant treatment in a heated air of 240°C to 260°C in a hot air circulation type flame-resistant furnace with an elongation ratio of -3.9% for 66 minutes to obtain a flame-resistant fiber bundle, then subjected to pre-carbonization treatment under a nitrogen atmosphere in a heat treatment furnace having a maximum temperature of 700°C with an elongation ratio of 1.5% for about 1.5 minutes, and subsequently subjected to carbonization treatment under a nitrogen atmosphere in a heat treatment furnace having a maximum temperature of 1,350°C with an elongation ratio of -4.5% for about 1.5 minutes to obtain a carbonized fiber bundle.

[0102] Next, a carbonized fiber bundle was allowed to travel in a 5% by mass aqueous solution of ammonium bicarbonate, and the carbonized fiber bundle as a positive electrode was subjected to energization treatment between with the counter electrode such that the amount of electricity is 30 coulomb per 1 g of the carbonized fiber bundle, then washed with warm water at 90°C, and dried. Subsequently, the carbon fiber bundle was immersed in a water dispersion containing 6.0% of a sizing agent containing a bisphenol A type epoxy resin as a main component. Next, the carbonized fiber strand was passed through the nip roller, and then brought into contact with a roller heated to 150°C for 30 seconds to dry moisture, thereby obtaining a carbonized fiber bundle in which 1.6 wt% of a sizing agent was adhered to the carbon fiber bundle.

[0103] A step of averaging the carbonized fiber bundles to which the sizing agent was adhered, was run. As the averaging member, the parallel rods having two cylinders with a diameter of 5 mm and arranged in parallel with a distance between the centers of 30 mm were used, and the parallel rods were disposed perpendicular to a surface of the fiber bundle having a width direction. The setting angle of the parallel rods was adjusted such that the gap between the cylinders was 0 mm when viewed in a traveling direction of the carbonized fiber bundle. The carbonized fiber bundle was twisted 90° in the axial direction by the parallel rods, passed such that the carbon fiber bundle was brought into contact with the parallel rods in a state where the width direction of the fiber bundle is the vertical direction, then twisted back 90° by a horizontal roller, and wound on 10 spools.

[0104] Various evaluations of the carbon fiber bundle thus obtained were carried out. To measure the thickness of the carbon fiber bundle, using a two-dimensional laser displacement sensor (manufactured by KEYENCE CORPORATION, sensor head: LJ-V7080, controller: LJ-V7000), thickness data is acquired simultaneously in a line in a width direction of the carbon fiber bundle. The results are shown in Table 1.

[0105] In Examples, the variation rate of the thickness of the carbon fiber bundle was half or less, which was a favorable result, as compared with Comparative Examples including the conventional step in which there was no parallel rod as the averaging member.

[0106] In addition, the cantilever value and the stickability were lower than in Comparative Examples, and it was found that the fiber bundles were loosened.

[0107] In the carbon fiber bundle obtained in these Examples, the variation rate of the thickness of the fiber bundle in the width direction of the fiber bundle is small, and thus a constant amount of resin can be applied to a unit amount of the carbon fibers by a touch roll method. Therefore, the fiber content in the molded article becomes uniform.

[Comparative Examples 1 to 4]

[0108] A carbon fiber bundle was obtained in the same manner as in Example 1 except that the carbon fiber bundle was wound on four spools at the winding portion without running the step of homogenizing the carbon fiber bundle after the sizing step. Table 1 shows the results of various evaluations. The obtained carbon fiber bundle had a variation rate of the thickness of the carbon fiber bundle of more than 35%, which was poor.

[Table 1]

	Variation rate of width of fiber bundle of carbon fiber bundle	Variation rate of thickness of fiber bundle of carbon fiber bundle in width direction of fiber bundle	Cantilever value	Stickability	Fiber-fiber dynamic friction coefficient	Fiber-metal dynamic friction coefficient	Amount of abrasion fluff	Tow width	Tow thickness	Flatness
	[%]	[%]								
Example 1	10.5	13.8	230	0.16	0.166	0.152	0.01	16.5	0.193	85.5
Example 2	11.5	14.8	250	0.15	0.17	0.154	0.01	14.8	0.24	61.7
Example 3	10.6	14.3	210	0.15	0.168	0.152	0.01	15.5	0.217	71.4
Example 4	10.8	14.6	220	0.14	0.162	0.15	0.01	15.1	0.217	69.6
Example 5	11.2	162	200	0.16	0.165	0.152	0.03	14.9	0.239	62.3
Example 6	11.7	17.4	200	0.17	0.174	0.162	0.03	14.6	0.241	60.6
Example 7	11.8	18.4	265	0.19	0.168	0.158	0.05	13.9	0.252	55.2
Example 8	11.6	17.8	260	0.19	0.172	0.158	0.04	14.7	0.246	59.8
Example 9	12.3	18.1	260	0.19	0.164	0.157	0.04	13.7	0.262	52.3
Example 10	12	19.1	270	0.2	0.166	0.156	0.05	13.8	0.253	54.5
Average value	11.4	16.5	236.5	0.2	0.168	0.155	0.028	14.75	0.236	62.5
Comparative Example 1	142	37.4	270	0.21	0.172	0.165	0.11	14.8	0.231	64.1
Comparative Example 2	14.5	38.6	280	0.22	0.168	0.155	0.13	14.4	0.245	58.8
Comparative Example 3	156	39.8	270	0.22	0.175	0.163	0.15	13.6	0.257	52.9
Comparative Example 4	15.1	38.2	270	0.21	0.164	0.154	0.14	14.2	0.252	56.3
Average value	14.9	38.5	272.5	0.215	0.170	0.159	0.133	14.25	0.246	57.9

[Industrial Applicability]

[0109] The carbon fiber bundle of the present invention is capable of obtaining molded products which has a good handling during high-order processing and which has carbon fibers uniformly distributed, even when the carbon fiber bundle has a large total fineness.

[Reference Signs List]

[0110]

- 1: Drive roller
- 2: Carbon fiber bundle
- 3: Free roller
- 4: Weight
- 5: Spring scale
- 6: Parallel rods (averaging member)
- 7: Carbonized fiber bundle
- 8: Sizing agent bath
- 9: Dryer
- 10: Winder
- 11: Free roll
- A: Arrangement place of averaging member

Claims

1. A carbon fiber bundle having a total fineness of 2 g/m or more and a variation rate of a thickness of the fiber bundle in a width direction of the fiber bundle of 30% or less.
2. The carbon fiber bundle according to Claim 1, wherein the number of single fibers is 20,000 or more.
3. The carbon fiber bundle according to Claim 1 or 2, wherein the fiber has an average thickness of 0.18 to 0.28 mm.
4. The carbon fiber bundle according to any one of Claims 1 to 3, wherein the fiber bundle has a variation rate of a width in a length direction of the fiber bundle of 13% or less.
5. The carbon fiber bundle according to any one of Claims 1 to 4, wherein the fiber bundle has a width of 13 to 18 mm.
6. The carbon fiber bundle according to any one of Claims 1 to 5, wherein the fiber bundle has a flatness (width/average thickness) of 60 to 70.
7. The carbon fiber bundle according to any one of Claims 1 to 6, wherein a cantilever value is 210 to 250 mm and a stickability is 0.18 m or less.
8. The carbon fiber bundle according to any one of Claims 1 to 7, wherein an adhesion amount of a sizing agent is 0% to 20% by mass.
9. The carbon fiber bundle according to any one of Claims 1 to 8, wherein a fiber-fiber dynamic friction coefficient is 0.2 or less.
10. The carbon fiber bundle according to any one of Claims 1 to 9, wherein a fiber-metal dynamic friction coefficient is 0.18 or less.
11. A manufacturing method of a carbon fiber bundle, comprising:
in an averaging member having two or more parallel rods arranged between a sizing agent dryer and a winder or

a transfer device, passing a carbonized fiber bundle through the averaging member such that each of a surface A of the carbonized fiber bundle and a surface B of the carbonized fiber bundle opposite side to the surface A comes into contact with the rods at least once or more.

- 5 **12.** The manufacturing method of a carbon fiber bundle according to Claim 11,
 wherein a distance between adjacent rods of the parallel rods is 15 to 50 mm.
- 13.** The manufacturing method of a carbon fiber bundle according to Claim 11 or 12,
 wherein in the passing the carbonized fiber bundle, the carbonized fiber bundle is passed such that the carbonized
10 fiber bundle is brought into contact with the parallel rods in a state where a surface direction of a carbon fiber bundle
 in contact with a roller one before the parallel rods is twisted by 90°.
- 14.** The manufacturing method of a carbon fiber bundle according to any one of Claims 11 to 13,
 wherein in the passing the carbonized fiber bundle, the carbonized fiber bundle is passed such that a maximum
15 width of the carbonized fiber bundle in contact with the parallel rods is 5% to 20% wide with respect to a width of a
 carbon fiber bundle in contact with a roller one before the parallel rods.
- 15.** The manufacturing method according to Claim 13 or 14,
20 wherein the roller is located upstream of the parallel rods in a traveling direction of the carbonized fiber bundle, and
 a length direction of the roller and a length direction of the parallel rods are substantially perpendicular to each
 other.
- 16.** The manufacturing method according to any one of Claims 13 to 15,
25 wherein a distance from a center of the roller to a center of the parallel rods is preferably 200 to 1,500 mm and more
 preferably 500 to 1,000 mm at a position where the distance is shortest.
- 17.** The manufacturing method of a carbon fiber bundle according to any of Claims 11 to 16,
 wherein in the passing the carbonized fiber bundle, the carbonized fiber bundle is flat, and the carbonized fiber
30 bundle is passed through the averaging member such that one surface A of the carbonized fiber bundle is brought
 into contact with the parallel rods located upstream in a traveling direction of the carbonized fiber bundle and then
 the other surface B of the carbonized fiber bundle is brought into contact with the parallel rods located downstream
 in the traveling direction of the carbonized fiber bundle.
- 18.** The manufacturing method of a carbon fiber bundle according to any of Claims 11 to 17, the manufacturing method
35 comprising:
 before the passing the carbonized fiber bundle, changing a direction of a surface of the carbonized fiber bundle with
 a length direction of the carbonized fiber bundle as an axis.
- 19.** The manufacturing method according to Claim 18,
40 wherein in changing the direction of the surface, the surface of the carbonized fiber bundle is preferably tilted in a
 width direction within a range of 30° to 150° with the length direction of the carbonized fiber bundle as the axis, the
 surface of the carbonized fiber bundle is more preferably tilted in the width direction within a range of 45° to 135°
 with the length direction of the carbonized fiber bundle as the axis, the surface of the carbonized fiber bundle is
45 even more preferably tilted in the width direction within a range of 60° to 120° with the length direction of the
 carbonized fiber bundle as the axis, and the surface of the carbonized fiber bundle is particularly preferably tilted in
 the width direction by 90° with the length direction of the carbonized fiber bundle as the axis.
- 20.** The manufacturing method according to Claim 18 or 19,
50 wherein the changing the direction of the surface is performed between a roller located upstream of the two or more
 parallel rods in the traveling direction of the carbonized fiber bundle, and the parallel rods located most upstream
 among the two or more parallel rods.
- 21.** The manufacturing method according to any of claims 11 to 20, which is a manufacturing method of the carbon fiber
55 bundle according to any of claims 1 to 10.

FIG. 1

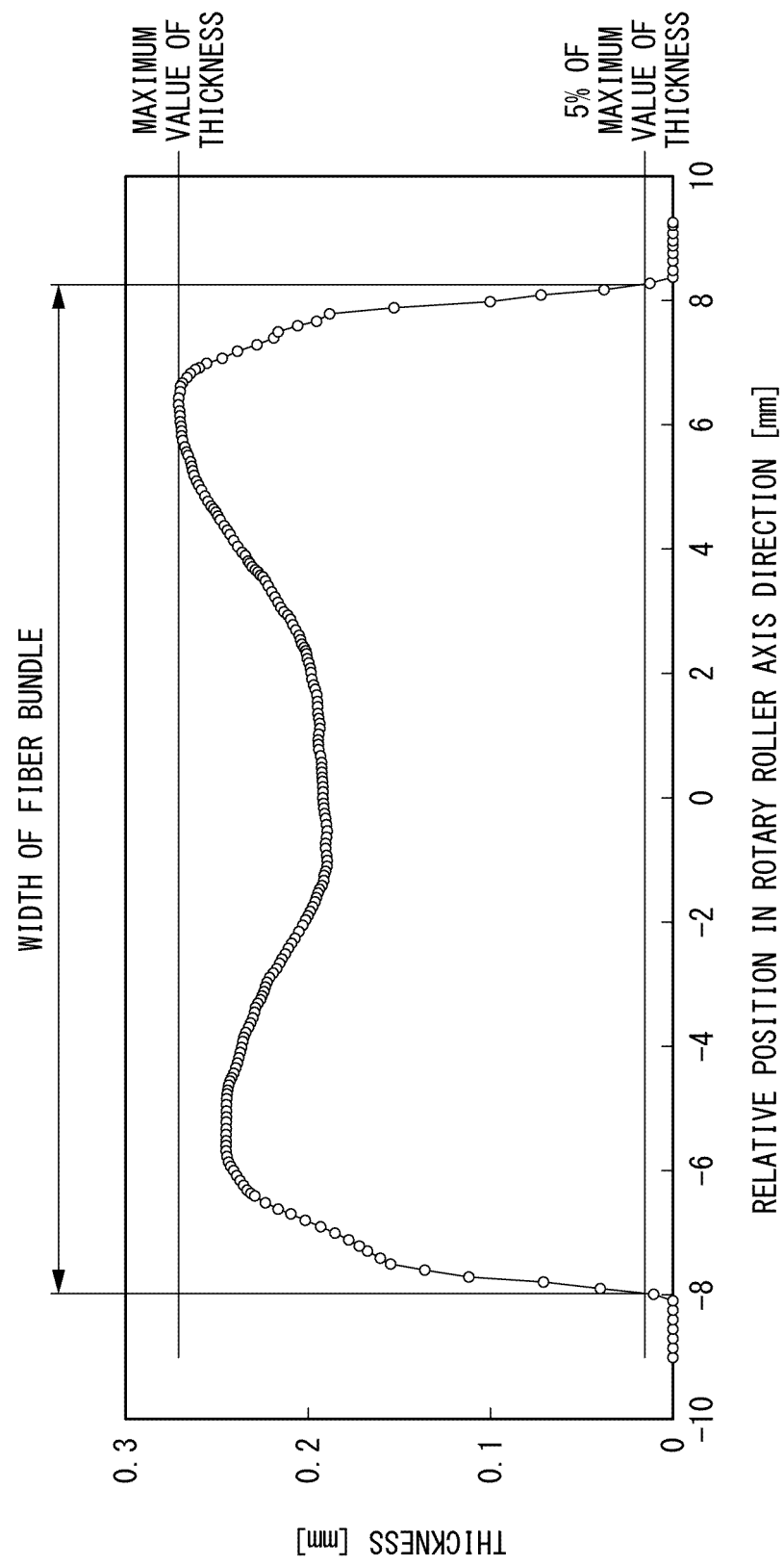


FIG. 2

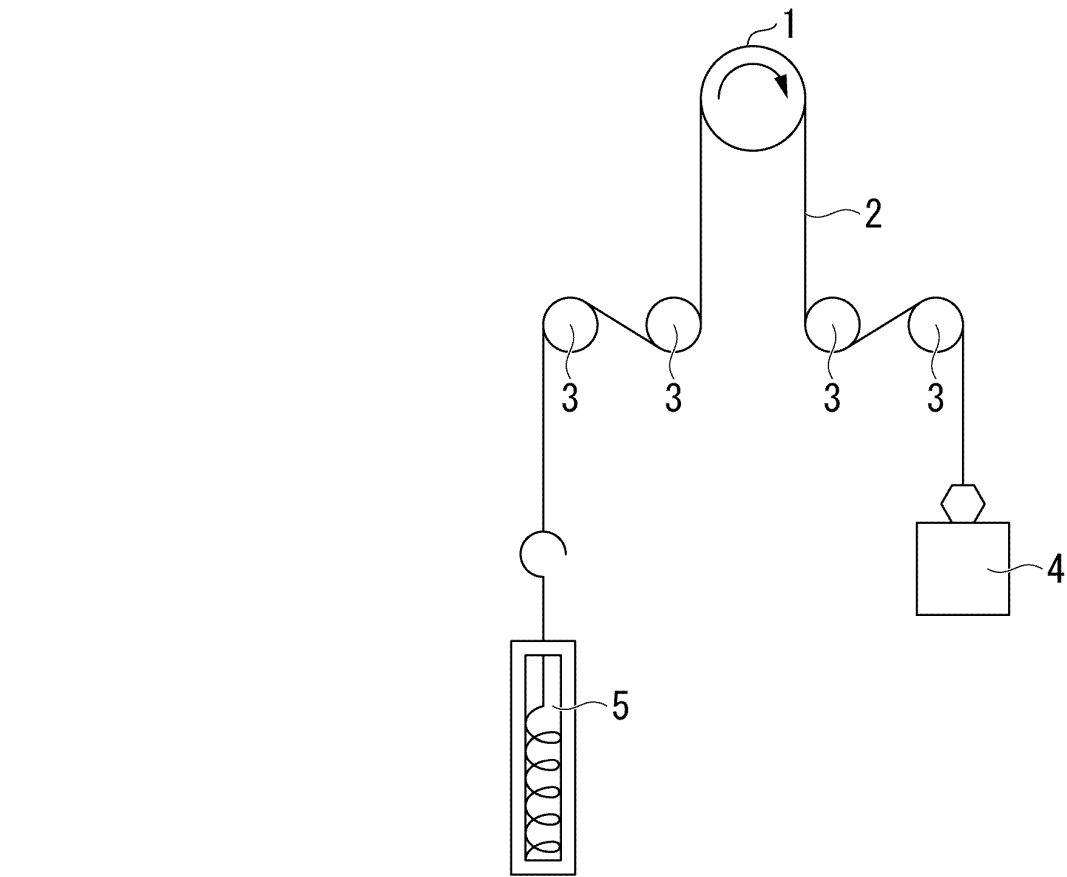


FIG. 3

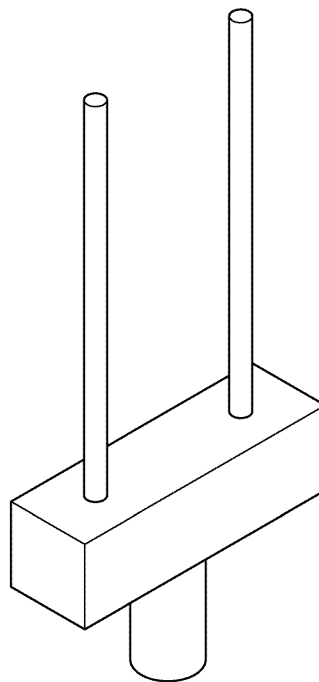


FIG. 4

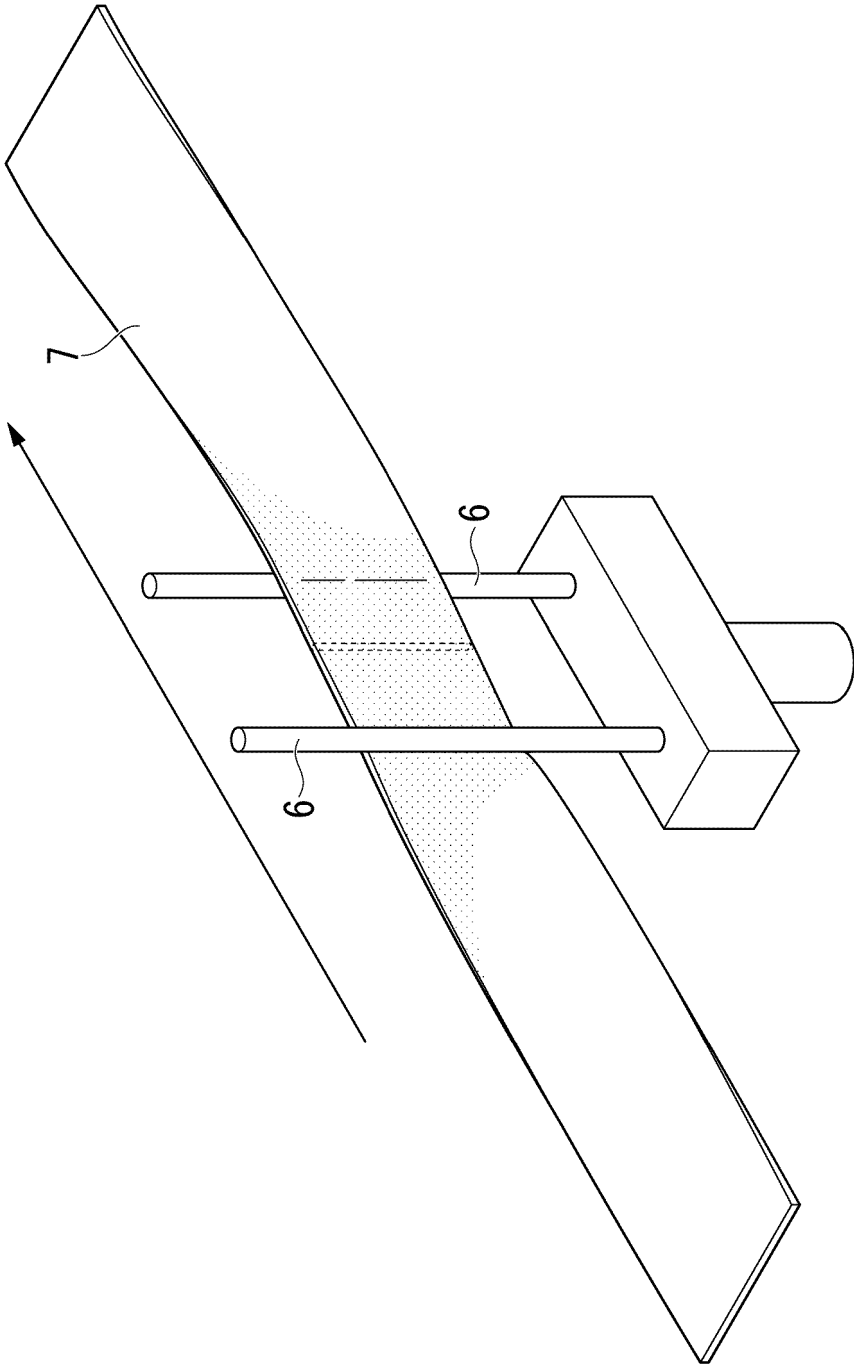
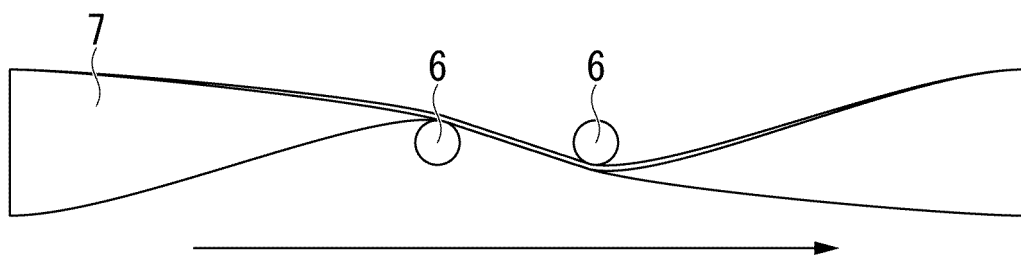


FIG. 5



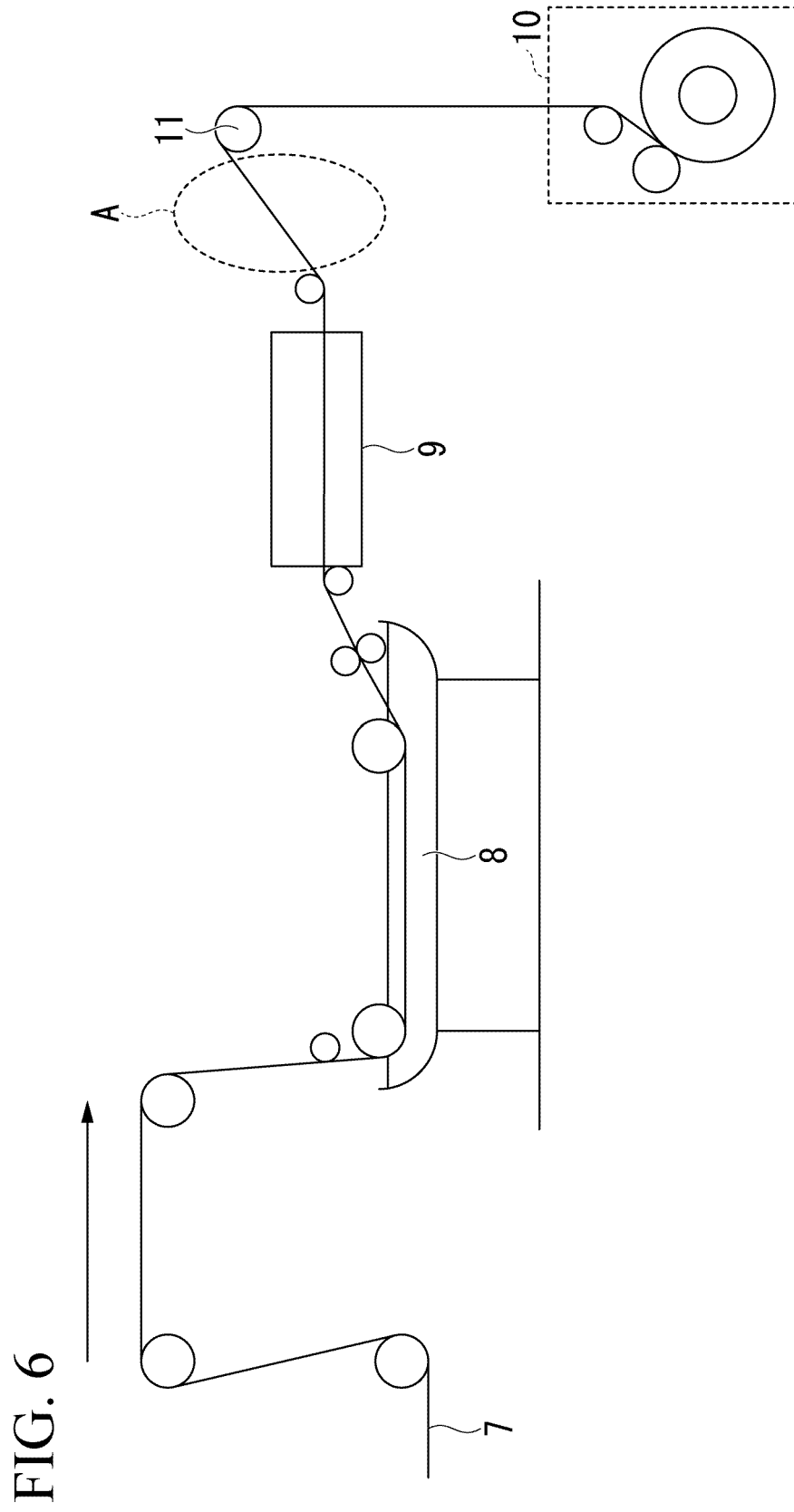
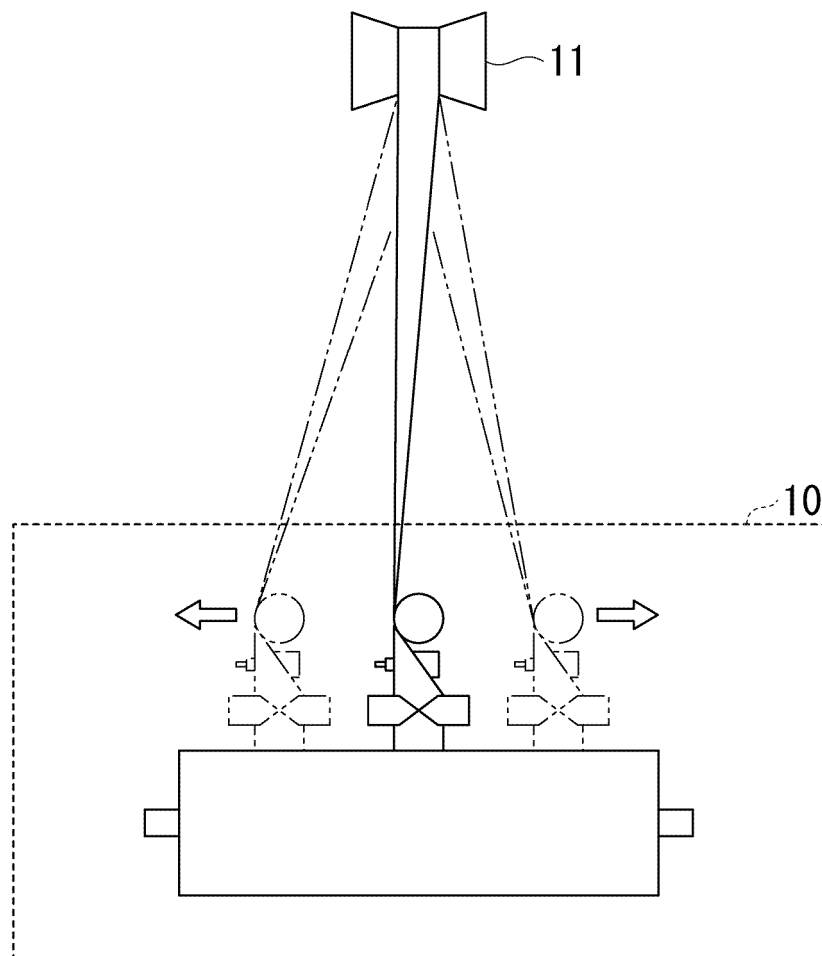


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/014411

A. CLASSIFICATION OF SUBJECT MATTER <i>D01F 9/22</i> (2006.01)i; <i>D02J 1/18</i> (2006.01)i FI: D01F9/22; D02J1/18 Z 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) D01F9/08-13/04, D02G1/00-3/48, D02J1/00-13/00, D06B1/00-23/30, D06C3/00-29/00, D06G1/00-5/00, D06H1/00-7/24, D06J1/00-1/12 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 1971-2022 Registered utility model specifications of Japan 1996-2022 Published registered utility model applications of Japan 1994-2022 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) JSTPlus/JMEDPlus/JST7580 (JDreamIII)																		
C. DOCUMENTS CONSIDERED TO BE RELEVANT																			
<table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>WO 2018/212016 A1 (SHINRYO CORP.) 22 November 2018 (2018-11-22)</td> <td>1-21</td> </tr> <tr> <td>A</td> <td>WO 2019/146484 A1 (TORAY INDUSTRIES, INC.) 01 August 2019 (2019-08-01)</td> <td>1-21</td> </tr> <tr> <td>A</td> <td>CN 112048854 A (HENGSHEN CO., LTD.) 08 December 2020 (2020-12-08)</td> <td>1-21</td> </tr> <tr> <td>A</td> <td>JP 01-282362 A (NIPPON OIL CO., LTD.) 14 November 1989 (1989-11-14)</td> <td>1-21</td> </tr> <tr> <td>A</td> <td>JP 2006-305854 A (TORAY INDUSTRIES, INC.) 09 November 2006 (2006-11-09)</td> <td>1-21</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	A	WO 2018/212016 A1 (SHINRYO CORP.) 22 November 2018 (2018-11-22)	1-21	A	WO 2019/146484 A1 (TORAY INDUSTRIES, INC.) 01 August 2019 (2019-08-01)	1-21	A	CN 112048854 A (HENGSHEN CO., LTD.) 08 December 2020 (2020-12-08)	1-21	A	JP 01-282362 A (NIPPON OIL CO., LTD.) 14 November 1989 (1989-11-14)	1-21	A	JP 2006-305854 A (TORAY INDUSTRIES, INC.) 09 November 2006 (2006-11-09)	1-21	☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex. * Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family
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A	JP 2006-305854 A (TORAY INDUSTRIES, INC.) 09 November 2006 (2006-11-09)	1-21																	
Date of the actual completion of the international search 12 May 2022	Date of mailing of the international search report 31 May 2022																		
Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan	Authorized officer Telephone No.																		

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/014411

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

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

(Invention 1) Claims 1-10 and 21

Claims 1-10 and 21 have the special technical feature wherein the rate of variation in the thickness of a fiber bundle in the width direction of the fiber bundle is 30% or less; thus these claims are classified as invention 1.

(Invention 2) Claims 11-20

Claims 11-20 do not share any technical features with claim 1 classified as invention 1. In addition, there are not the same or corresponding special technical features between these inventions.

Furthermore, claims 11-20 do not depend from claim 1. In addition, claims 11-20 are not substantially identical to or similarly closely related to any of the claims classified as invention 1.

Accordingly claims 11-20 cannot be identified as invention 1.

Meanwhile, claims 11-20 have the special technical feature of an averaging member having two or more parallel rods disposed between a sizing agent dryer and a winder or a putting-in device, wherein a surface A of the carbonized fiber bundle and a surface B opposite to the surface A are each brought into contact with the rods one or more times, and the carbonized fiber bundle thus passes through the averaging member; thus these claims are classified as invention 2.

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

Remark on Protest

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/014411

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

REFERENCES CITED IN THE DESCRIPTION

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