



(11)

EP 4 826 144 A1

(12)

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

(43) Date of publication:
21.10.2026 Bulletin 2026/43

(51) International Patent Classification (IPC):
D01F 6/60 (2006.01)

(21) Application number: **24903621.1**

(52) Cooperative Patent Classification (CPC):
D01F 6/60

(22) Date of filing: **06.12.2024**

(86) International application number:
PCT/JP2024/043187

(87) International publication number:
WO 2025/126965 (19.06.2025 Gazette 2025/25)

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

(72) Inventors:
• **NAGASE, Akimi**
Okazaki-shi, Aichi 444-8522 (JP)
• **SHIGENO, Hisao**
Okazaki-shi, Aichi 444-8522 (JP)
• **MINAI, Kazushi**
Okazaki-shi, Aichi 444-8522 (JP)

(30) Priority: **14.12.2023 JP 2023210980**

(74) Representative: **Mewburn Ellis LLP**
Aurora Building
Counterslip
Bristol BS1 6BX (GB)

(71) Applicant: **Toray Industries, Inc.**
Tokyo 103-8666 (JP)

(54) **MATERIAL-RECYCLED NYLON 66 FIBER**

(57) A recycled nylon 66 fiber containing 5% by weight or more of recycled nylon 66, having a total fineness of 110 to 2100 dtex, a strength of 7.6 to 10.0 cN/dtex, and an elongation of 15.0 to 35.0%. A material-recycled nylon 66 fiber that has high strength and a good fuzz quality is provided.

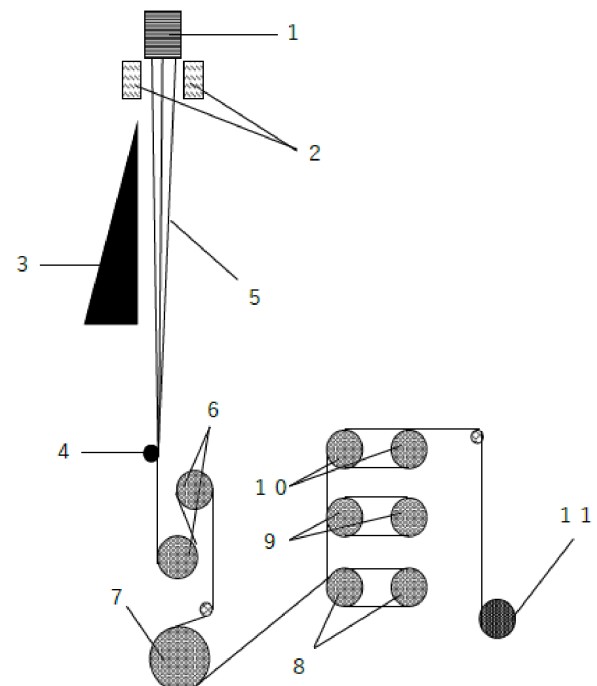


Fig. 1

EP 4 826 144 A1

Description

TECHNICAL FIELD

- 5 **[0001]** The present invention relates to a nylon 66 fiber using a material-recycled polyhexamethylene adipamide resin and a method for producing the same.

BACKGROUND ART

- 10 **[0002]** Since multifilaments of nylon 6 and nylon 66 have higher strength and elongation and superior fuzz quality as compared with general-purpose multifilaments of polyester, polypropylene, and the like, they are used in a wide variety of industrial applications such as airbags, tire cords, sports racket strings, ropes, fishing nets, and bag belts.

- [0003]** In addition, due to the recent increase in environmental awareness, the value of environmentally friendly materials, for example, products prepared using recycled raw materials is increasing, and development of fibers prepared using recycled raw materials is required.

- 15 **[0004]** Nylon 6 and polyesters can be relatively easily subjected to material recycling, and methods for producing recycled fibers having substantially the same physical properties as virgin fibers are disclosed as in the following Patent Documents 1 and 2.

- [0005]** Patent Document 3 discloses a method for producing a recycled nylon fiber by pulverizing nylon scraps including a nylon 66 full-bright fiber, a nylon 66 semi-dull fiber, a nylon 66 dull fiber, a nylon 66 ultrahigh-tenacity fiber, a nylon 66 high-tenacity fiber, a nylon 66 fine denier high-tenacity fiber, a nylon 66 fish net fiber waste, and a nylon 66 cloth waste, then washing the nylon scraps to reduce an oil component to 0.22% by weight, subjecting the nylon scraps to dehydration and a melt granulation step to produce material-recycled nylon resin chips, and melt-spinning the material-recycled nylon chips. However, in Patent Document 3, the draw ratio is set to 1.2 to 1.5 times in the drawing process included in the fiber production process, and it is stated that when the draw ratio exceeds 1.5 times, the yarn tends to be broken due to excessive drawing, and thus it is obvious that the strength level required for industrial fibers cannot be achieved.

PRIOR ART DOCUMENTS

30

PATENT DOCUMENTS

[0006]

- 35 Patent Document 1: WO 2022/196407 A
Patent Document 2: JP 2003-13328 A
Patent Document 3: JP 6629943 B2

SUMMARY OF THE INVENTION

40

PROBLEMS TO BE SOLVED BY THE INVENTION

- [0007]** However, nylon 66 has a problem in that thermal/oxidative degradation and gelation easily occur as compared with other polymers, and the degree of difficulty in recycling is high.

- 45 **[0008]** An object of the present invention is to solve the above problems, and is to obtain a material-recycled nylon 66 fiber that has strength and elongation and fuzz quality equivalent to those of a virgin 100% nylon 66 fiber while inhibiting polymer degradation due to thermal/oxidative degradation and the like.

SOLUTIONS TO THE PROBLEMS

50

- [0009]** The present invention has been made as a result of intensive study to solve the above problems, and has the following configurations.

- 55 (1) A recycled nylon 66 fiber containing 5% by weight or more of recycled nylon 66, having a total fineness of 110 to 2100 dtex, a strength of 7.6 to 10.0 cN/dtex, and an elongation of 15.0 to 35.0%.
(2) The recycled nylon 66 fiber according to (1), wherein a UVA value at a wavelength of 290 nm at a solution concentration of 5 mg/mL is 0.30 or less.
(3) The recycled nylon 66 fiber according to (1) or (2), wherein the recycled nylon 66 fiber has a number of fuzzes

of 0 to 3 fuzzes/10,000 m.

(4) The recycled nylon 66 fiber according to any one of (1) to (3), wherein the recycled nylon 66 fiber is produced from chips prepared by repelletizing any one or more among fiber production process scraps, airbag base fabric selvage scraps, base fabric scraps generated in refining processing, unqualified airbag scraps, scraps generated in cutting or sewing airbags, and airbags recovered from scrapped vehicles as a raw material.

(5) A woven fabric for an airbag, comprising the recycled nylon 66 fiber according to (1) or (2).

(6) A tire cord comprising the recycled nylon 66 fiber according to (1) or (2).

(7) A racket string comprising the recycled nylon 66 fiber according to (1) or (2).

(8) A V-ribbed belt comprising the recycled nylon 66 fiber according to (1) or (2).

(9) A woven fabric for a bag, comprising the recycled nylon 66 fiber according to (1) or (2).

EFFECTS OF THE INVENTION

[0010] The present invention makes it possible to obtain a material-recycled nylon 66 fiber having strength and elongation equivalent to those of a virgin 100% nylon 66 fiber and a good fuzz quality.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Fig. 1 is a schematic view of a material-recycled nylon 66 fiber production process of the present invention.

EMBODIMENTS OF THE INVENTION

[0012] Hereinafter, the present invention will be described in detail.

[0013] The material-recycled nylon 66 fiber according to the embodiment of the present invention is preferably nylon 66 in which a material-recycled polyhexamethylene adipamide resin is blended at an amount of 5% by weight or more of the fiber. That is, the recycled nylon 66 fiber of the present invention contains 5% by weight or more of a material-recycled polyhexamethylene adipamide resin. From the viewpoint of increasing awareness of global environmental conservation in recent years, the blending amount is preferably as large as possible, and 20% by weight to 100% by weight of the fibers are preferably nylon 66 fibers blended with a material-recycled polyhexamethylene adipamide resin.

[0014] The polyhexamethylene adipamide resin may contain, for example, 10 mol% or less of another copolymerization component as long as the effects of the present invention are not impaired, but it is preferable that the polyhexamethylene adipamide resin contains a large amount of hexamethylene adipamide units because the regularity of the molecular chains of the resulting fiber is enhanced, and oriented crystallization in the yarn making process is facilitated, so that fibers excellent in mechanical properties are obtained. The content of the hexamethylene adipamide units is more preferably 95 mol% or more, and still more preferably 98 mol% or more.

[0015] The recycled nylon 66 fiber of the present invention may contain, as necessary, a terminal blocking agent such as monocarboxylic acid, a matting agent such as titanium oxide, a polymerization catalyst and a heat resistance agent such as a phosphorus compound, an antioxidant and a heat resistance stabilizer such as a copper compound and a halide of an alkali metal or an alkaline earth metal as components other than nylon, but the content of the nylon component is preferably 95% by weight or more, and more preferably 97% by weight or more. When the content of the nylon component is less than 95% by weight, this is not preferable because the heat resistance of the nylon deteriorates.

[0016] The recycled nylon 66 fiber of the present invention has a total fineness of 110 to 2100 dtex. The total fineness is preferably in a range of 350 to 2100 dtex. When the fineness is less than 110 dtex, since the fineness is excessively small, the recycled nylon 66 fiber cannot withstand mechanical drawing at a draw ratio for achieving high strength, so that the possibility of fuzz generation increases. When the fineness exceeds 2100 dtex, this is not preferable because the cooling efficiency lowers and mechanical characteristics deteriorate. The single fiber fineness is preferably 2 to 35 dtex. When the single fiber fineness is 2 to 35 dtex, it is possible to stably obtain a recycled 66 fiber having high strength while maintaining the quality. The number of single yarns is not particularly regulated, and what is important is the single fiber fineness.

[0017] The strength of the recycled nylon 66 fiber of the present invention is 7.6 to 10.0 cN/dtex. The strength is preferably 8.0 to 9.7 cN/dtex, and more preferably 8.5 to 9.7 cN/dtex. When the strength is in such a range, the nylon fiber is suitable for industrial materials such as airbags, and for textiles for clothing having excellent durability. When the strength is less than 7.6 cN/dtex, it is insufficient for improving the durability of fibers for industrial materials such as airbags. When a nylon fiber having a strength exceeding 10.0 cN/dtex is intended to be obtained, mechanical drawing is performed at a high draw ratio, and the fuzz quality is deteriorated. Such recycled nylon 66 fibers are not preferable because they are unsuitable for fibers for industrial materials such as airbags required to have a good

quality.

[0018] The elongation is 15.0% to 35.0%, and preferably 17.0% to 30.0%. The elongation is preferably as high as possible, but is actually 35.0% or less in order to afford a prescribed strength with nylon. Within this range, the toughness and the amount of work to break of the material-recycled nylon 66 fiber can be increased, and excellent durability can be maintained.

[0019] Although depending also on the total fineness and the single fiber fineness, the toughness is preferably $38 \text{ cN/dtex} \times \sqrt{\%}$ or more, and more preferably $40 \text{ cN/dtex} \times \sqrt{\%}$ or more. Having a high toughness makes it possible to inhibit generation of fuzzes, yarn breakage, and the like, and thus, to obtain a material-recycled nylon 66 fiber having extremely high quality even having high strength. The strength (cN/dtex) and the elongation (%) are values measured under a constant speed elongation condition shown in JIS L 1013 (1999) 8.5.1 Standard Condition Test, and the toughness is a value calculated by $\text{strength} \times \sqrt{\text{elongation}}$.

[0020] The number of fuzzes of the recycled nylon 66 fiber of the present invention is preferably 0 to 3 fuzzes/10,000 m, particularly preferably 0 to 2 fuzzes/10,000 m, and further preferably 0 to 1 fuzz/10,000 m. Having a smaller number of fuzzes makes it possible to expand the uses to articles desired to have an excellent fuzz quality, such as airbags. In this regard, the number of fuzzes refers to a value converted to the number of fuzzes/10,000 m from the total number of fuzzes measured along a filament having a length of 100,000 m or more while the filament is rewound at a rate of 150 m/minute.

[0021] The UVA value (absorbance) at a wavelength of 290 nm at a solution concentration of 5 mg/mL of the recycled nylon 66 fiber of the present invention is preferably 0.30 or less. The UVA value is more preferably 0.27 or less, and still more preferably 0.24 or less. It is known that nylon exhibits absorption of a carbonyl group in the vicinity of 290 nm as degradation progresses, and the degree of degradation of a polymer can be quantitatively evaluated by measuring the absorption. When the UVA value at a wavelength of 290 nm exceeds 0.30, degradation of the polymer has proceeded, and therefore fibers having high strength and elongation as described above cannot be obtained.

[0022] In the following, a method for producing material-recycled polyhexamethylene adipamide resin chips (hereinafter referred to as nylon 66 chips) to be used for the material-recycled nylon 66 fiber according to an embodiment of the present invention will be described.

[0023] The nylon 66 process scraps to be used for the production of nylon 66 chips in an embodiment of the present invention are those generated in a fiber production process and an airbag base fabric production process, and examples thereof include: fiber production process scraps, such as fiber scraps generated after attachment of a spinneret and before collection as a fiber product such as a drum package (swept scraps), fiber scraps generated due to yarn breakage troubles or the like in a spinning process, a drawing process, or the like (yarn breakage scraps), and scraps that have been obtained as a final form of a fiber product such as a drum package and unqualified in product selection (product scraps); selvedge scraps generated in weaving an airbag base fabric (airbag base fabric selvedge scraps); scraps generated in refining processing an airbag base fabric (base fabric scraps generated in airbag refining); scraps that have been obtained as a final form of an airbag base fabric and unqualified in product sorting (unqualified airbag scraps); and scraps generated in cutting or sewing an airbag from an airbag base fabric (scraps generated in cutting or sewing airbags). Any process scraps can be suitably used. In addition, not only process scraps but also an airbag obtained by dismantling and separating from scrapped vehicles (airbags recovered from scrapped vehicles) can be used.

[0024] The process for producing nylon 66 chips in the embodiment of the present invention preferably includes the steps of melting, filtering, and discharging scraps, water-cooling and cutting of the discharged resin, and immersing the chips in hot water. In addition, before melting scraps, cutting of the scraps, immersion of the scraps in hot water, and pulverization of the scraps may be appropriately performed. Further, after the water-cooling and cutting of the discharged resin, the chips may be subjected to immersion in hot water. Each of the steps will be described below.

[0025] The moisture content of the nylon 66 process scraps to be used for the production of nylon 66 chips in the embodiment of the present invention is preferably 30,000 ppm or less. As a result of intensive studies, the inventors have found that when a yarn is produced using chips prepared by repelletizing nylon 66 process scraps having a moisture content of 30,000 ppm or less, a yarn having a UVA value prescribed in the present invention is obtained, and a material-recycled nylon 66 fiber having excellent strength and elongation is obtained.

[0026] As a method of adjusting the moisture content of the nylon 66 process scraps within the above range, for example, there is a method of subjecting the nylon 66 process scraps to a vacuum drying oven set at 100°C, but the method of adjusting the moisture content is not limited to the method described in the description herein.

[0027] The prepared scraps are subjected to a melting, filtering and discharging step. Examples of the melting method include a method using a pressure melter or an extruder, and nylon 66 chips can be produced by any melting method. Further, the extruder may be either a single-screw type or a twin-screw type.

[0028] The partial pressure of oxygen of the melting section atmosphere is preferably in the range of 1 to 1000 Pa, and more preferably 1 to 500 Pa. Nylon 66 is a polymer that is more likely to undergo oxidative degradation and associated gelation than other polymers, and has a high degree of difficulty in recycling. Then, the inventors have

intensively studied, and have found that oxidative degradation during melting can be inhibited by adjusting the partial pressure of oxygen in the melting section atmosphere to the above range and inhibiting the contact between the polymer and oxygen as much as possible. To adjust the partial pressure of oxygen of the melting section atmosphere to the above range, it is preferable to perform replacement (purge) with an inert gas such as helium, argon, or nitrogen, or to perform vacuuming.

[0029] The melting temperature at which the fiber scraps melt is 240 to 360°C. When the melting temperature is 240°C or more, there is no occurrence of non-melting, and it is possible to stably produce nylon 66 chips without a trouble such as an increase in filtration pressure in a melting system. When the melting temperature is 360°C or less, preferably 340°C or less, it is possible to inhibit thermal degradation of nylon 66 chips.

[0030] It is extremely important to perform filtration along with melting of the fiber scraps. Foreign substances can be removed from the nylon 66 chips by performing filtration along with melting. As a result, an increase in the internal pressure of the spinning pack at the time of producing the nylon 66 fiber is suppressed, so that spinning troubles such as leakage from the pack and discharge abnormalities are reduced, and the nylon 66 fiber can be produced with good processability.

[0031] As a filtration filter, it is preferable to use a filtration filter having a filtration accuracy of 5 to 50 μm . When the filtration accuracy is 5 μm or more, the fiber scraps can be stably melted without increasing the pressure due to clogging of the filter in the melting system. When the filtration accuracy is 50 μm or less, foreign substances can be removed from the nylon 66 chips. Regarding the filtration filter, any filter such as a wire mesh filter, a metal nonwoven fabric filter, and a metal short fiber filter can be used as long as the filtration is performed normally.

[0032] The melting and filtration time is preferably 5 min/kg or less. When the melting and filtration time is 5 min/kg or less, thermal degradation of the nylon 66 chips due to the thermal history through the melting and the filtration can be inhibited, and yellowing of nylon 66 fibers to be obtained can be suppressed.

[0033] The melted and filtered nylon 66 resin is discharged through a die to be pelletized. When the nylon 66 resin is discharged through the die, the nylon 66 resin is preferably discharged to form pellets having a diameter of 1 to 3 mm.

[0034] The nylon 66 resin discharged through the die is subjected to a water-cooling and cutting step. Water cooling of the nylon 66 resin is merely required to be able to cool the nylon 66 resin to such an extent that it can be easily cut. The nylon 66 resin may be cut by a known method, but is preferably cut to a length of 1 to 4 mm.

[0035] Fig. 1 is a schematic diagram of a machine for direct spin draw preferably used in the present invention.

[0036] Hereinafter, a method for producing the material-recycled nylon 66 fiber of the present invention will be described with reference to Fig. 1 as an example.

[0037] First, raw material chips of nylon to serve as a raw material of the material-recycled nylon 66 fiber of the present invention are prepared. As a polymerization method for producing the nylon, a known polymerization method can be used.

[0038] The relative viscosity in sulfuric acid (hereinafter, referred to as viscosity) of the raw material chips of the recycled nylon 66 fiber of the present invention is preferably 2.8 to 3.9, and more preferably 3.0 to 3.9. When material-recycled nylon 66 chips and virgin nylon 66 chips are weighed and mixed, it is merely required that a value obtained by weighted average according to the viscosity and proportion of each type of the chips is included in the above range. When the viscosity of the chips exceeds 3.9, adjusting the total fineness within the range regulated in the present invention leads to generation of minute foreign matters caused by thickening, thermal degradation, gelation, and the like due to long-term stay of the polymer, and the fuzz quality is deteriorated. When the viscosity of the chips is less than 2.8, it is difficult to obtain a recycled nylon 66 fiber having strength regulated in the present invention. The relative viscosity in sulfuric acid refers to a value obtained by dissolving a sample in 98% sulfuric acid and measuring the relative viscosity in sulfuric acid at 25°C using an Ostwald viscometer.

[0039] The recycled nylon 66 fiber of the present invention is preferably produced by performing a production process including so-called normal melt spinning, cooling, oiling, and drawing after weighing material-recycled nylon 66 chips or weighing and mixing material-recycled nylon 66 chips and virgin nylon 66 chips and drying them to adjust the moisture content to a prescribed value. The manufacturing apparatus to be used in the embodiment of the present invention includes a mixing device capable of weighing and mixing material-recycled nylon 66 chips and virgin nylon 66 chips in a melt spinning device or separately from the melt spinning device. The melt spinning device to be used in the embodiment of the present invention can be used in either an extruder type spinning machine or a pressure melter type spinning machine. In the case of adding a colorant, chips obtained by mixing master chips to which a colorant is added at a high concentration with base chips may be charged into a spinning machine, or each type of chips may be charged while being weighed immediately above the spinning machine. The colorant may be directly charged into the spinning machine in a powder or liquid state.

[0040] Then, the weighed nylon chips are fed to an extruder type spinning machine, delivered to a spinneret with a metering pump, and melt-spun. When this is done, the pressure at the feeding unit in the extruder is preferably in a vacuum state (pressure: 0.0 kPa) in order to inhibit the thickening, thermal degradation, and gelation of the polymer. The spinning temperature is set to a value 50°C higher than the melting point of the polymer. The nylon discharged

through the spinneret 1 is preferably forced to pass through a heating cylinder 2 surrounding the range 5 to 300 cm immediately below the spinneret. The temperature in the heating cylinder is -30 to +30°C in a preferable aspect and is more preferably -15 to +15°C with respect to the melting point of the polymer nylon. Slowly cooling the spun yarn through a high-temperature atmosphere surrounded by the heating cylinder without immediately cooling the spun yarn allows the molecular orientation of the melt-spun nylon to be relaxed and the molecular orientation uniformity among the single fibers to be enhanced, and thus can increase the strength of the material-recycled nylon 66 fiber. On the other hand, if cooling is performed immediately without passing through the high-temperature atmosphere, the orientation of the undrawn yarn is enhanced, and the variation in the orientation degree among the single fibers is increased. Heat-drawing such an undrawn yarn results in a possibility of failing to obtain a material-recycled nylon 66 fiber having high strength.

[0041] The undrawn yarn 5 that has passed through the high temperature atmosphere is then cooled and solidified by blowing air at 10 to 80°C, preferably 10 to 50°C by a cross flow cooling device 3. When the cooling air is hotter than 80°C, swaying of single fibers increases during spinning, and thus collision or the like between the single fibers occurs, which causes deterioration of yarn spinnability.

[0042] Then, the cooled yarn obtained is provided with an oil agent using a known oil supply device 4, taken up on a take-up roller 6 (1FR), drawn, and then may be wound up. As the oil agent, any known oil agent can be used. The amount of application is preferably 0.3 to 1.5% by weight, and still more preferably 0.5 to 1.0% by weight, to inhibit the wrapping of the single yarns around the take-up roller 6.

[0043] In addition, the spinning speed defined by the rotation speed of the take-up roller 6 is preferably 500 to 1000 m/min, and more preferably 600 to 800 m/min. When the spinning speed is 500 m/min or more, the final production speed is also sufficient, and the material-recycled nylon 66 fiber can be produced with high production efficiency and at low cost. When the spinning speed is 1000 m/min or less, frequent occurrence of yarn breakage and fuzz can be prevented, which is preferable. The drawing speed represented by the maximum speed of the drawing roll is preferably 2,800 m/min or more, and more preferably 3,000 m/min or more.

[0044] The spun yarn obtained by the methods described above can be subjected to drawing, relaxation heat treatment, winding, and the like using known methods. Specifically describing the case of two-stage drawing as an example, the spun yarn taken up by the take-up roller 6 is wound in the order of a yarn supplying roller 7 (2FR), a first drawing roller 8 (1DR), a second drawing roller 9 (2DR), and a relaxation roller 10 (RR), subjected to a heat treatment and a drawing treatment, and wound around a winder 11.

[0045] Pre-stretch drawing is performed between 1FR and 2FR, first stage drawing is performed between 2FR and 1DR, and second stage drawing is performed between 1DR and 2DR. It is preferable that the temperature of 2FR is set to 30 to 50°C, and the temperature of 1DR is set to 100 to 225°C, and pre-stretch drawing and first stage drawing are performed by thermal drawing at around the glass transition temperature. The remaining drawing and heat setting are typically preferably performed at a high temperature ranging from 180 to 240°C. The temperature is more preferably 200 to 220°C.

[0046] Regarding the total draw ratio (hereinafter, also simply referred to as a draw ratio), that is, the ratio between the take-up roller 6 and the second drawing roller 9, in order to obtain a recycled nylon 66 fiber having high strength, it is preferable to employ a high draw ratio, and drawing may be performed at 3.8 to 5.0 times within the fineness range described in the present invention. Note that the winding speed is typically preferably 2000 to 5000 m/min, and more preferably 2500 to 4500 m/min. In addition, it is preferable to wind up the yarn to form a cheese package with the winding device under the condition of a winding tension of 20 to 250 gf.

[0047] The method as described above allows production of a recycled nylon 66 fiber having high strength and a good fuzz quality described in the present invention.

EXAMPLES

[0048] Hereinafter, the present invention will be described in more detail with reference to Examples. The definition and measurement method of each characteristic in the present invention are as follows.

[0049]

(1) Relative viscosity in sulfuric acid (η_r): Using a polymer chip or a fiber as a sample, 0.25 g of the sample was dissolved in 25 ml of 98% sulfuric acid, and measurement was performed at 25°C using an Ostwald viscometer to provide the relative viscosity in sulfuric acid (η_r) from the following formula. The measured value was calculated from the average value of five samples.

$$\eta_r = [\text{the number of seconds that the sample solution flows down}] / [\text{the number of seconds that only sulfuric acid flows down}]$$

(2) UVA value (absorbance): Using a polymer chip or a fiber as a sample, 1 g or 0.1 g of the sample was dissolved in 20 ml of special grade formic acid, and the absorbance at 290 nm was read from a spectrum measured at a temperature of 25°C in a wavelength range of 250 to 340 nm using a recording spectrophotometer U-3900H manufactured by HITACHI, Ltd.

(3) The total fineness was measured in accordance with JIS L 1090 (1999).

(4) Number of single fibers: The number of single fibers was calculated by the method of JIS L 1013 (1999) 8.4.

(5) Single fiber fineness: The single fiber fineness was calculated by dividing the total fineness by the number of single fibers.

(6) Tenacity, strength, and elongation: The measurement was performed under constant speed elongation conditions defined in JIS L 1013 (1999) 8.5.1, Standard Condition Test. A sample was measured using "TENSILON" UCT-100 manufactured by Orientec Corporation, at a holding interval of 25 cm and a tensile speed of 30 cm/min. The tenacity was determined from the maximum tenacity in the S-S curve, the elongation was determined from the elongation at the point showing the maximum tenacity in the S-S curve, and the strength was determined by dividing the tenacity by the total fineness.

(7) Number of fuzzes in yarn making: The yarn package obtained was rewound at a speed of 150 m/min, a laser type fuzz detector "FLYTECH V" manufactured by Heberlein was installed 2 m away from the yarn during rewinding, and the total number of fuzzes detected was evaluated. The evaluation was performed for 100000 m or more, and the total number was converted to the number per 10000 m, which was indicated as the number of fuzzes.

(Example 1)

<Production of virgin nylon 66 chips>

[0050] A 5% by weight aqueous solution of copper acetate as an antioxidant was added to and mixed with the nylon 66 chips obtained by the liquid phase polymerization, and 68 ppm of copper with respect to the polymer weight was added and adsorbed. Then, a 50% by weight aqueous solution of potassium iodide and a 20% by weight 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, and solid-phase polymerization was performed using a batch-type solid-phase polymerization apparatus to provide nylon 66 chips having a relative viscosity in sulfuric acid of 3.75.

<Production of material-recycled nylon 66 chips>

[0051] The unqualified airbag scraps were melted at a temperature of 340°C with a pressure melter with a partial pressure of oxygen of 50 Pa by N₂ purge and vacuuming, and the molten polymer was guided to a single-screw extruder. The melting temperature in the extruder was set to 290°C, melting was performed while maintaining a tip pressure of 8 MPa, and filtration was performed through a nonwoven fabric filter with a filtration accuracy of 37 μm. At that time, the discharge rate was adjusted such that the total melting and filtration time was 5 min/kg. The filtered molten polymer was discharged from a die, cooled with water, and cut, affording material-recycled nylon 66 chips having a diameter of 1.2 mm and a length of 2.0 mm.

<Production of material-recycled nylon 66 fiber>

[0052] The obtained virgin nylon 66 chips and material-recycled nylon 66 chips were weighed and mixed at a ratio described in Table 1, then fed to an extruder having a diameter of 110 mm, and melted at a melting temperature of 300°C under vacuum. The discharge rate of the molten polymer was adjusted by a metering pump such that multifilaments having a total fineness of 470 dtex were obtained, and the molten polymer was delivered to a spinning pack. Thereafter, filtration was performed through a metal nonwoven fabric filter having a filtration accuracy of 15 μm in the spinning pack, and then spinning was performed through a spinneret having 72 circular holes. A heating cylinder having a heating cylinder length of 15 cm was placed 3 cm below the spinneret surface, and heated such that the in-cylinder atmosphere temperature was 250°C. Herein, the in-cylinder atmosphere temperature is an air temperature at a portion 1 cm away from the inner wall at the center of the heating cylinder length. A uniflow-type chimney designed to blow air in one direction was attached immediately below the heating cylinder, and cold air at 20°C was blown to the yarn at a speed of 35 m/min to cool and solidify the yarn. Then, the yarn was provided with an oil agent.

[0053] The undrawn yarn provided with the oil agent was wound and taken up in 1FR rotating at a surface speed of 818 m/min, and then drawn at a total draw ratio of 4.5 times. The taken-up yarn was continuously stretched by 5% between the take-up roller and 2FR without being wound up once, and then successively drawn in the first stage at a rotation speed ratio of 2.80 times, then drawn in the second stage at a rotation speed ratio of 1.46 times, and wound

up at a speed of 3358 m/min. The roller surfaces of 1FR and 2FR were mirror finished, and 1DR, 2DR, and RR were satin finished. The roller temperatures of 1FR were non-heated, 2FR was 40°C, 1DR was 150°C, 2DR was 225°C, and RR was 150°C. Such melt spinning and drawing afforded a material-recycled nylon 66 fiber. The entangling treatment was performed by injecting high-pressure 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 0.4 MPa.

(Example 2)

[0054] The same procedure as in Example 1 was conducted except that the raw material of the material-recycled nylon 66 chips was changed to fiber production process scraps, the total draw ratio was changed to 4.8 times, and the proportion of recycled chips was changed to 100%.

(Example 3)

[0055] The same procedure as in Example 1 was conducted except that the raw material of the material-recycled nylon 66 chips was changed to airbag base fabric selvage scraps, the total draw ratio was changed to 4.6 times, the proportion of recycled chips was changed to 50%, and the total fineness of the material-recycled nylon 66 fiber was changed to 110 dtex.

(Example 4)

[0056] The same procedure as in Example 1 was conducted except that the raw material of the material-recycled nylon 66 chips was changed to scraps generated in cutting or sewing airbags, the total draw ratio was changed to 5.8 times, the drawing speed was changed to 2645 m/min, the proportion of recycled chips was changed to 5%, and the total fineness of the material-recycled nylon 66 fiber was changed to 1400 dtex.

(Example 5)

[0057] The same procedure as in Example 1 was conducted except that the raw material of the material-recycled nylon 66 chips was changed to airbags recovered from scrapped vehicles, the total draw ratio was changed to 5.7 times, the drawing speed was changed to 2050 m/min, and the total fineness of the material-recycled nylon 66 fiber was changed to 2100 dtex.

(Example 6)

[0058] The same procedure as in Example 1 was conducted except that the raw material of the material-recycled nylon 66 chips was changed to base fabric scraps generated in refining processing, the melting section atmosphere during the production of the material-recycled nylon 66 chips was changed to vacuum, and the total fineness of the material-recycled nylon 66 fiber was changed to 350 dtex.

(Comparative Example 1)

[0059] The same procedure as in Example 1 was conducted except that the proportion of the raw material chips used was changed to 100% of virgin chips and the total draw ratio was changed to 4.4 times.

(Comparative Example 2)

[0060] The same procedure as in Example 1 was conducted except that the melting section atmosphere during the production of the material-recycled nylon 66 chips was changed to normal atmosphere.

(Comparative Example 3)

[0061] The same procedure as in Example 1 was conducted except that the raw material moisture content of the material-recycled nylon 66 chips was changed to 49000 ppm, and the proportion of the recycled chips was changed to 100%.

(Comparative Example 4)

[0062] The same procedure as in Example 1 was conducted except that the raw material moisture content of the material-recycled nylon 66 chips was changed to 150000 ppm, and the proportion of the recycled chips was changed to 100%.

5

10

15

20

25

30

35

40

45

50

55

[Table 1]

Material-recycled chip	Melt filtration	Recycled raw material	-	Comparative Example 1	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Comparative Example 2	Comparative Example 3	Comparative Example 4
				-	Airbag grade C scraps	Fiber production process scraps	Airbag base fabric selvage scrap	Scrap generated in cutting or sewing airbag	Airbag re-covered from scrapped vehicle	Base fabric scrap generated in refining processing	Base fabric scrap generated in refining processing	Fiber production process scraps	Fiber production process scraps
		ppm		-	13000	22000	15000	13000	13000	13000	13000	49000	150000
		-		-	N2	N2	N2	N2	N2	Vacuum	Atmosphere	N2	N2
		Pa		-	50	50	50	50	50	400	21000	50	50
		°C		-	340	340	340	340	340	340	340	340	340
		μm		-	37	37	37	37	37	37	37	37	37
		min/kg		-	5	5	5	5	5	5	5	5	5
				-	3.34	3.14	3.16	3.02	3.07	3.72	3.21	3.21	3.11
	Chip characteristics	Viscosity of chips		-	2.15	2.05	2.20	2.24	2.52	2.32	4.52	3.50	4.48
		UVA value at 290 nm (solution concentration 50 mg/mL)		-	0.22	0.21	0.22	0.22	0.25	0.23	0.45	0.35	0.45
		UVA value at 290 nm (solution concentration 5 mg/mL)		-	0.22	0.21	0.22	0.22	0.25	0.23	0.45	0.35	0.45

(continued)

Material- recycled fiber	Spinning con- ditions	Moisture con- tent of chips	ppm	Comparative Example 1	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Comparative Example 2	Comparative Example 3	Comparative Example 4
		Filtration ac- curacy	μm	15	15	15	15	15	15	15	15	15	15
		Total draw ra- tio	times	4.4	4.5	4.8	4.6	5.8	5.7	4.5	4.5	4.5	4.5
		Drawing speed	m/min	3600	3600	3600	3600	2645	2050	3600	3600	3600	3600
		Content ratio of material- recycled ny- lon 66	%	0	20	100	50	5	20	20	20	100	100
		Weighted average visc- osity of virgin chips and material-re- cycled chips	-	3.78	3.69	3.14	3.47	3.74	3.64	3.77	3.67	3.21	3.11

(continued)

Raw yarn characteristics	Comparative Example 1	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Comparative Example 2	Comparative Example 3	Comparative Example 4
	UVA value at 290 nm (solution concentration 50 mg/mL)	UVA value at 290 nm (solution concentration 5 mg/mL)	Total fineness	Tenacity	Elongation at break	Toughness	Number of fuzzes	fuzzes/10,000 m		
-	2.20	2.15	2.23	2.32	2.42	2.35	2.25	3.10	3.72	4.52
-	0.22	0.22	0.22	0.23	0.24	0.24	0.23	0.31	0.37	0.45
dtex	470	470	470	110	1400	2100	350	470	470	470
cN/dtex	8.5	8.5	7.6	8.0	9.7	9.2	8.6	7.3	7.0	6.6
%	23.5	22.8	25.0	23.9	19.9	20.5	23.0	22.5	22.5	23.0
cN/dtex ₅₀ %	41.2	40.6	38.0	39.1	43.3	41.7	41.2	34.6	33.2	31.7
fuzzes/10,000 m	0	0	0	1	2	1	0	10	5	8

[0063] The results of evaluating physical properties of the virgin nylon 66 fiber obtained in Comparative Example 1 and the material-recycled nylon 66 fibers obtained in Examples 1 to 6 and Comparative Examples 2 to 4 are shown in Table 1.

[0064] As is clear from Table 1, the material-recycled nylon 66 fiber of the present invention has a good fuzz quality while having strength and elongation equivalent to the virgin nylon 66 fiber.

[0065] In Examples 1 to 5, material-recycled nylon 66 fibers of the present invention were produced by variously changing the type of the recycled raw material, the content ratio of the material-recycled nylon 66, and the total fineness of the fiber, and in any case, the yarn characteristics comparable to those of the virgin nylon 66 fiber were obtained.

[0066] In the case where the pre-melting atmosphere in the production of the material-recycled nylon 66 chips was changed to vacuum as in Example 6, the moisture contained in the recycled raw material was removed and the viscosity of chips increased, but the UVA value was not deteriorated, and the yarn characteristics equivalent to those of the virgin fiber were obtained as recycled fibers. On the other hand, in the case where the pre-melting atmosphere in the production of the material-recycled nylon 66 chips was changed to the atmosphere as in Comparative Example 2, it can be seen that the UVA value was deteriorated, and the strength and elongation and the fuzz quality of the yarn were deteriorated as compared with the virgin fiber.

[0067] In addition, even in the cases where the moisture content of the process scraps as a raw material of the material-recycled nylon 66 chips exceeded 30,000 ppm as in Comparative Examples 3 and 4, the UVA value of the chips was deteriorated, and as a result, the strength and elongation of the yarn were deteriorated as compared with the virgin fiber.

[0068] From the above results, it is suggested that it is important to reduce the partial pressure of oxygen in the pre-melting atmosphere in the production of the material-recycled nylon 66 chips and to keep the moisture content of the process scraps as a raw material of the material-recycled nylon 66 chips within a regulated range for producing material-recycled nylon 66 fibers having high strength and a good fuzz quality suitable for industrial material applications.

INDUSTRIAL APPLICABILITY

[0069] Since the material-recycled nylon 66 fiber of the present invention has high strength and a good fuzz quality, it is suitable mainly for making industrial materials such as airbags and tire cords into sustainable materials.

DESCRIPTION OF REFERENCE SIGNS

[0070]

- 1: Spinneret
- 2: Heating cylinder
- 3: Cross flow cooling device
- 4: Oil supply device
- 5: Yarn
- 6: Take-up roller(1FR)
- 7: Yarn supplying roller(2FR)
- 8: First drawing roller(1DR)
- 9: Second drawing roller(2DR)
- 10: Relaxation roller(RR)
- 11: Winder

Claims

1. A recycled nylon 66 fiber containing 5% by weight or more of recycled nylon 66, having a total fineness of 110 to 2100 dtex, a strength of 7.6 to 10.0 cN/dtex, and an elongation of 15.0 to 35.0%.
2. The recycled nylon 66 fiber according to claim 1, wherein a UVA value (absorbance) at a wavelength of 290 nm at a solution concentration of 5 mg/mL is 0.30 or less.
3. The recycled nylon 66 fiber according to claim 1 or 2, wherein the recycled nylon 66 fiber has a number of fuzzes of 0 to 3 fuzzes/10,000 m.

4. The recycled nylon 66 fiber according to any one of claims 1 to 3, wherein the recycled nylon 66 fiber is produced from chips prepared by repelletizing any one or more among fiber production process scraps, airbag base fabric selvedge scraps, base fabric scraps generated in refining processing, unqualified airbag scraps, scraps generated in cutting or sewing airbags, and airbags recovered from scrapped vehicles as a raw material.

5

5. A woven fabric for an airbag, comprising the recycled nylon 66 fiber according to claim 1 or 2.

6. A tire cord comprising the recycled nylon 66 fiber according to claim 1 or 2.

10

7. A racket string comprising the recycled nylon 66 fiber according to claim 1 or 2.

8. A V-ribbed belt comprising the recycled nylon 66 fiber according to claim 1 or 2.

9. A woven fabric for a bag, comprising the recycled nylon 66 fiber according to claim 1 or 2.

15

20

25

30

35

40

45

50

55

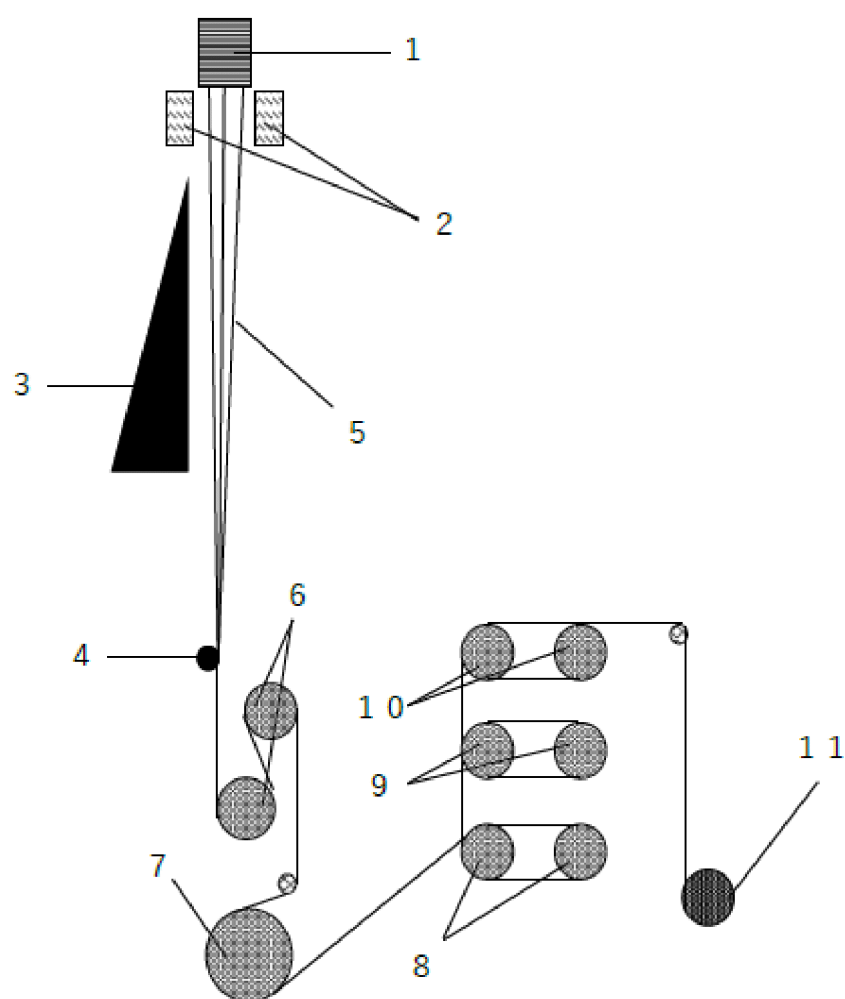


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/043187

A. CLASSIFICATION OF SUBJECT MATTER

D01F 6/60(2006.01)i

FI: D01F6/60 351B; D01F6/60 ZAB

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)

D01F6/60

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 1971-2025
 Registered utility model specifications of Japan 1996-2025
 Published registered utility model applications of Japan 1994-2025

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2022/039033 A1 (TORAY INDUSTRIES, INC.) 24 February 2022 (2022-02-24) claims, paragraph [0002], examples	1-9
Y	claims, paragraph [0002], examples	1-9
X	JP 2013-189744 A (TORAY INDUSTRIES, INC.) 26 September 2013 (2013-09-26) claims	1-5
A	entire text	6-9
X	JP 2009-243030 A (TORAY INDUSTRIES, INC.) 22 October 2009 (2009-10-22) claims 7, 8	1-5
A	entire text	6-9
Y	JP 2003-171356 A (TOYOTA JIDOSHA KABUSHIKI KAISHA) 20 June 2003 (2003-06-20) claims, paragraphs [0005], [0049]	1-9
Y	JP 59-187639 A (TORAY INDUSTRIES, INC.) 24 October 1984 (1984-10-24) claims	6



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

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

18 February 2025

Date of mailing of the international search report

04 March 2025

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.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2024/043187

5

10

15

20

25

30

35

40

45

50

55

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-194152 A (MITSUBOSHI BELTING LTD.) 09 July 2003 (2003-07-09) claims	8
A	WO 2023/167314 A1 (KAGOSHIMA UNIVERSITY) 07 September 2023 (2023-09-07) entire text, all drawings	1-9

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2024/043187

5

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO	2022/039033	A1	24 February 2022	US 2023/0279586 A1 claims, paragraph [0002], examples EP 4202093 A1 CN 115803484 A TW 202219342 A	
JP	2013-189744	A	26 September 2013	(Family: none)	
JP	2009-243030	A	22 October 2009	US 2011/0036447 A1 claims 7, 8 WO 2009/113325 A1 EP 2264235 A1 CN 102016143 A	
JP	2003-171356	A	20 June 2003	(Family: none)	
JP	59-187639	A	24 October 1984	(Family: none)	
JP	2003-194152	A	09 July 2003	(Family: none)	
WO	2023/167314	A1	07 September 2023	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2022196407 A [0006]
- JP 2003013328 A [0006]
- JP 6629943 B [0006]

Non-patent literature cited in the description

- 8.5.1 Standard Condition Test. *JIS L 1013*, 1999
[0019]