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(71) Applicant: **Kolon Industries, Inc.**
Gwacheon-si, Gyeonggi-do 427-709 (KR)

(72) Inventors:
- **KIM, Young-Jo**
  Gimpo-si
  Gyeonggi-do 415-060 (KR)
- **KIM, Gi-Woong**
  Daegu 706-020 (KR)
- **AN, Byoung-Wook**
  Incheon 407-765 (KR)
- **LEE, Sang-Mok**
  Gumi-si
  Gyeongsangbuk-do 730-020 (KR)
- **LEE, Young-Soo**
  Gumi-si
  Gyeongsangbuk-do 730-030 (KR)

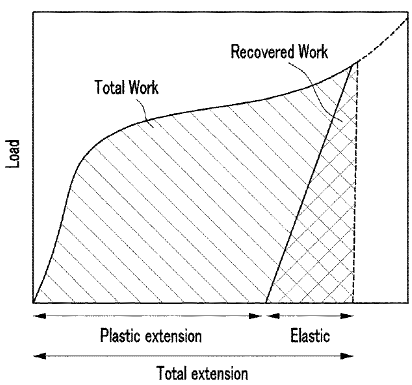
(74) Representative: **Ter Meer Steinmeister & Partner**
Patentanwälte
Mauerkircherstrasse 45
81679 München (DE)

(54) POLYESTER FIBER AND METHOD FOR PRODUCING SAME

(57) The present invention relates to a high strength and high elongation polyester fiber being used for anchoring, mooring, or towing a ship. Particularly, the present invention relates to a polyester fiber wherein the recovered work ratio at the elongation corresponding to 10% of the maximum load measured at room temperature is 70% or more, the recovered work ratio at the elongation corresponding to 20% of the maximum load is 50% or more, and the recovered work ratio at the elongation corresponding to 30% of the maximum load is 40% or more, a method of preparing the same, and a polyester fiber rope including the same.

Since the polyester fiber of the present invention has sufficient strength and elongation and secures superior mechanical properties by including the filaments having the high strength, the high elongation, and the high recovered work ratio, it becomes possible to prepare the rope which can minimize the fiber breaking, can improve the shock absorption performance noticeably, and can secure the superior life and the sufficient stability of the rope, even if there is a change of external environment such as the rough sea and the severe rolling of a ship.

Fig. 2



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Description

BACKGROUND OF THE INVENTION

(a) Field of the Invention

[0001] The present invention relates to a high-strength polyester fiber for a rope being used for anchoring, mooring, or towing a ship, and a preparation method thereof. More specifically, the present invention relates to a polyester fiber of high elastic recovery (recovered work ratio) having superior mechanical properties and wear resistance, a low moisture absorption rate, a light resistance, a shock absorption performance, and the like, and a preparation method thereof.

(b) Description of the Related Art

[0002] A marine rope being used for anchoring, mooring, or towing a ship or an industrial rope being used in various construction sites has been developed in the direction of securing the superior mechanical property of high strength.

[0003] Particularly, in many fields of ships, a wire rope has been largely used because it can secure a high strength and a superior fatigue resistance, and a fiber rope consisting of a high performance nylon fiber or a polyolefin fiber has been used even in the case of using a synthetic fiber rope. But, there are problems that the wire rope is corroded by water and too rigid to hold the movement of a ship caused by a wave or a tidal difference and it may cause damage to a ship, and it is difficult to operate because of the weight of the rope itself. Existing nylon fiber ropes may cause a problem of frequent replacement because it has a large strength diminution rate to ultraviolet (UV) rays and the strength of the rope deteriorates excessively, and thus it loses the ability to hold the ship if it is used for a long time. Furthermore, since the nylon fiber rope has a high moisture absorption rate, it is not easy to operate when it is used for mooring or anchoring a ship, and it may cause a personal accident if the rope is frozen in a wet form in winter.

[0004] Meanwhile, a polyester represented by polyethylene terephthalate (hereinafter, 'PET') is being used widely to fibers, films, or resins because it is superior in mechanical properties and chemical resistance. For example, in the case of fiber, it is being used widely not only for clothes but also for various industrial materials such as a tire cord, a belt, a hose, a rope, and the like. However, the existing polyester fiber shows a low elongation property of high modulus and thus it cannot respond sufficiently to the deformation caused by the movement of a ship according to the change of the sea during anchoring a ship, and there is a problem of fiber breaking.

[0005] Therefore, we need the study for developing a high performance synthetic fiber which can improve the shock absorption performance against the change of external environment and can give superior mechanical properties and operation performance when the fiber is used to the marine rope being used for anchoring, mooring, or towing a ship, or the industrial rope.

SUMMARY OF THE INVENTION

[0006] It is an aspect of the present invention to provide a polyester fiber showing the characteristics of high strength, high elongation, and high elastic recovery, and having superior mechanical properties and wear resistance, a low moisture absorption rate, a light resistance, a shock absorption performance, and the like, so as to be used to the marine rope or the industrial rope.

[0007] It is another aspect of the present invention to provide a method of preparing said polyester fiber.

[0008] It is still another aspect of the present invention to provide a fiber rope including said polyester fiber.

[0009] The present invention provides a polyester fiber, wherein the recovered work ratio at the elongation corresponding to 10% of the maximum load measured at room temperature is 70% or more, the recovered work ratio at the elongation corresponding to 20% of the maximum load is 50% or more, and the recovered work ratio at the elongation corresponding to 30 % of the maximum load is 40 % or more.

[0010] The present invention also provides a method of preparing said polyester fiber, including the steps of preparing a polyester undrawn fiber by melt-spinning a polyester polymer having an intrinsic viscosity of 1.2 dl/g or more at 270 to 310 °C, and drawing the polyester undrawn fiber.

[0011] The present invention also provides a polyester fiber rope including said polyester fiber.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Fig. 1 is a schematic process drawing illustrating the preparation process of the polyester fiber according to one embodiment of the present invention.

Fig. 2 is an example of strength-elongation curve of a general fiber, the elastic recovery (recovered work ratio, %) can be calculated from the area of the strength-elongation curve.

Fig. 3 represents the strength-elongation curve of the polyester fiber according to Example 4 of the present invention.

Fig. 4 represents the strength-elongation curve of the polyester fiber according to Comparative Example 1 of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0013] Hereinafter, the polyester fiber which can be used to the marine rope or an industrial rope, the method of preparing the same, and the fiber rope including the same are explained in more detail, according to concrete embodiments of the present invention. However, the followings are only for the understanding of the present invention and the scope of the present invention is not limited to or by them, and it is obvious to a person skilled in the related art that the embodiments can be variously modified in the scope of the present invention.

[0014] In addition, "include" or "comprise" means to include any components (or ingredients) without particular limitation unless there is no particular mention about them in this description, and it cannot be interpreted as a meaning of excluding an addition of other components (or ingredients).

[0015] In the present invention, 'polyester fiber' means a fibrous polymer obtained by the esterification reaction of a diol compound and a dicarboxylic acid such as terephthalic acid generally. The polyester fiber corresponds to a basic fiber component for preparing 'the marine rope or the industrial rope' of the present invention. The polyester has a superior resistance against moisture and thus it is more preferable to prepare the fiber rope for replacing the marine wire rope.

[0016] In the present invention, any common polyester fiber may be used as the polyester fiber, for example, a polyalkylene terephthalate such as polyethylene terephthalate (PET), polyethylene naphthalate (PEN), polybutylene terephthalate (PBT), polycyclohexanedimethylene terephthalate (PCT), and the like, or a copolyester including the same as the main component may be used. Particularly, polyethylene terephthalate is more preferable to be used to the marine rope in the aspect of the properties of strength, elongation, and so on.

[0017] However, the polyester has lower polymerization efficiency than nylon, and the degradation of the molecular chain occurs much more because of severe hydrolysis by heat and moisture when it is made into a fiber, and thus it is difficult to obtain molecular chains having high molecular weight. Therefore, high drawing ratio is applied during the spinning process in order to obtain high strength with short molecular chain, and the properties of high strength, low elongation, and high modulus are obtained by this. Like this, it has been difficult to obtain the polyester fiber having high recovered work ratio because existing polyesters have short molecular chains. Meanwhile, nylon can show the properties of high strength, high elongation, and high recovered work ratio in addition to low modulus. If a ship is anchored by using the rope made of the fiber having low recovered work ratio like existing polyester fibers, the rope may be broken by the wild sea or a repetitive change of external environment due to its elastic recovery and it may cause a breakage of the ship because it is impossible to act as a buffer to the external shock and the external environmental shock is directly delivered to the ship.

[0018] Accordingly, the present invention can be applied effectively to the preparation of the marine fiber rope or the industrial fiber rope which can maintain sufficient strength and elongation against the external environment change and can maintain the long time shock absorption performance, by optimizing the properties of the polyester fiber, especially, the recovered work ratio, to high levels in order to have superior recovery rate against the repetitive change.

[0019] Particularly, as experimental results of the present inventors, it is revealed that lower moisture absorption rate and more improved light resistance can be obtained in company with superior mechanical properties by preparing the marine or industrial rope by using the polyester fiber having a certain characteristic.

[0020] Therefore, according to one embodiment of the present invention, the present invention provides a polyester fiber having a certain characteristic. The polyester fiber may be the fiber wherein the recovered work ratio at the elongation corresponding to 10% of the maximum load measured at room temperature is 70% or more, the recovered work ratio at the elongation corresponding to 20% of the maximum load is 50% or more, and the recovered work ratio at the elongation corresponding to 30% of the maximum load is 40 % or more.

[0021] Such polyester fiber may preferably include polyethylene terephthalate (PET) as the main component. At this time, various additives may be included with PET in the preparation process, and the fiber may include 70 mol% or more, preferably 90 mol% or more, of PET in order to secure superior mechanical properties when it is made into the polyester fiber rope. Hereinafter, the term of polyethylene terephthalate (PET) means that 70mol% or more of polyethylene terephthalate is included, without particular explanation.

[0022] Since the polyester fiber according to one embodiment of the present invention is prepared under the below melt-spinning and drawing conditions, it becomes to show far superior elastic recovery against a repetitive deformation at room temperature to existing polyester fibers.

[0023] Existing polyesters generally show low elastic recovery characteristic due to its short molecular chain, and it becomes inferior in the long time shock absorption performance and wear resistance remarkably when they are made into the fiber rope. However, the polyester fiber obtained through the controlled melt-spinning and drawing process shows high elastic recovery characteristic and it can raise the shock absorption performance of the rope and can extend the life time of the rope owing to said characteristic. Furthermore, the polyester fiber of the present invention has the characteristic of minimized drawing in company with said high elastic recovery. Due to such high elastic recovery, the polyester fiber can resolve the problems of low wear resistance and deteriorated shock absorption performance shown in the fiber rope including the fiber having low elastic recovery, high modulus, and low elongation at break, and it is possible to obtain more improved shock absorption performance and extended life time of the rope in company with superior mechanical properties. Namely, the polyester fiber may show the recovered work ratio of 70% or more, preferably 75% or more, and more preferably 80% or more, at the elongation corresponding to 10% of the maximum load measured at room temperature. Furthermore, the polyester fiber may show the recovered work ratio of 50% or more, preferably 52% or more, and more preferably 54% or more, at the elongation corresponding to 20% of the maximum load. The polyester fiber also may show the recovered work ratio of 40 % or more, preferably 41% or more, and more preferably 42 % or more, at the elongation corresponding to 30% of the maximum load. Due to such high elastic recovery (recovered work ratio), the polyester fiber can resolve the problems of low wear resistance and deteriorated shock absorption performance shown in the fiber rope including the existing fiber having high modulus and low elongation at break, and it is possible to obtain more improved shock absorption performance and extended life time of the rope in company with superior mechanical properties.

[0024] At this time, the elastic recovery (recovered work ratio) of the polyester fiber may be a percentage value (%) of recovered work per total work in the stress-elongation graph obtained by a tensile test, as represented by the following Calculation Formula 1:

[Calculation Formula 1]

$$\text{Elastic Recovery (Recovered Work Ratio) of Fiber} = \{(\text{Area of Recovered Work}) / (\text{Area of Total Work})\} \times 100$$

[0025] Here, the total work is the value corresponding to the area of the strength-elongation curve of the fiber measured according to American Society for Testing and Materials standard ASTM D 2256 method at room temperature, as illustrated in Fig. 2. Furthermore, the recovered work is the value corresponding to the area of the strength-elongation curve measured after repeating the elongation corresponding to 10%, 20%, or 30% of the maximum load respectively and the release 10 times, as illustrated in Fig. 2. In the marine rope for anchoring or mooring a ship, if the recovered work ratio of the fiber is low like the existing polyester fibers, it cannot respond sufficiently to the deformation caused by the movement of the ship according to the change of the sea during anchoring the ship, and it loses the ability to hold the ship during anchoring the ship because it loses the elastic recovery after a period of use.

[0026] Particularly, the polyester fiber of the present invention is characterized in that the elastic recovery (work recovery) is optimized to maintain the initial designed properties even in the repetitive deformation and to be able to absorb the shock by the deformation, so that it can be used to the marine rope for anchoring, mooring, or towing a ship or to the industrial rope being used in various construction sites. In this aspect, the polyester fiber may have the recovered work ratio of 70% or more, 50% or more, and 40% or more respectively at the elongation corresponding to 10%, 20%, and 30% of the maximum load measured at room temperature, namely, the maximum tensile strength in the strength-elongation curve measured at room temperature. The reason for applying the elongation to the fiber until 30% is for considering the conditions for the rope design and the degree of maximum deformation during mooring a ship, and it is known in the field of shipbuilding industry that the recovered work ratio at the elongation corresponding to 10% of the maximum load is more important matter, because the deformation by external environment that the ship encounters most frequently during mooring in the sea is the level of within 10% of the maximum load. For more concrete example, namely, in the case of designing the rope for holding a ship, it is possible to design the rope in the light of that the force for holding a ship against the movement by a tidal difference needs just within 10% of the maximum load and the force for holding a ship against the movement by the wind and waves by typhoon needs 30% of the maximum load when anchoring a ship.

[0027] Furthermore, the polyester fiber may show more improved intrinsic viscosity in comparison with formerly known polyester fibers, namely, it may show the intrinsic viscosity of 0.8 dl/g or more or 0.8 dl/g to 1.2 dl/g, preferably 0.85 dl/g or more or 0.85 dl/g to 1.15 dl/g, and more preferably 0.90 dl/g or more or 0.90 dl/g to 1.10 dl/g. So that the rope prepared by using the polyester fiber exhibits high mechanical properties and has superior wear resistance, it is preferable to have the intrinsic viscosity of such range.

[0028] The intrinsic viscosity of the fiber is preferably 0.8 dl/g or more so as to exhibit high strength with low elongation and satisfy the demanded strength for the marine or industrial fiber rope, and if not, it cannot help exhibiting the properties with high-drawing. Like this, it is possible to increase the entanglement and disorder between molecular chains and prevent the slip between molecular chains due to an external deformation, by means of securing long molecular chain by applying a low-drawing. If not, namely, if it has short molecular chains, the slip occurs between molecular chains by the external deformation and the shape is deformed, and it cannot function as a buffer to the external deformation because the mechanical and physical properties change, particularly, the elasticity deteriorates, according to this. Therefore, it is preferable to exhibit high strength property with a low-drawing by means of maintaining the intrinsic viscosity of the fiber to be 0.8 dl/g or more. Furthermore, it is preferable that the intrinsic viscosity of the polyester fiber is 1.2 dl/g or less, because when the intrinsic viscosity is over 1.2 dl/g, the drawing tension may increase during the drawing process and may cause a problem on the process. Particularly, the polyester fiber of the present invention can secure high strength characteristic sufficient to be effectively used for anchoring, mooring, or stowing a ship and can have more improved shock absorption property against the rolling of the ship due to the change of external environment, by maintaining the intrinsic viscosity of such high level.

[0029] Accordingly, it becomes possible to prepare the marine or industrial rope having superior mechanical properties, a wear resistance, and a shock absorption effect at the same time, by using the polyester fiber showing such high elastic recovery and high elongation, and preferably a high intrinsic viscosity. Therefore, if the polyester fiber is used to the rope, it decreases the deterioration in the strength caused by the moisture absorption and the ultraviolet rays remarkably and can secure the superior mechanical properties and strength maintenance rate as the marine or industrial rope. Simultaneously, the polyester fiber of the present invention improves the shock absorption performance against the rolling of the ship or the supporter according to the external change such as a tidal current or an air circulation and can decrease the occurrence of the fiber breaking remarkably.

[0030] Meanwhile, the polyester fiber according to one embodiment of the present invention may show the tensile tenacity of 8.0 g/ d or more or 8.3 g/d to 11.0 g/d, and preferably 8.5 g/d or more or 8.5 g/d to 10.0 g/d. Furthermore, the polyester fiber may show the elongation of 15% or more or 15% to 30%, and preferably 16 % or more or 16 % to 28%. The polyester fiber may show the dry heat shrinkage rate of 7% or less or 1.5% to 7%. The dry heat shrinkage rate is based on the value measured under the condition of giving the fixed load of 0.01 g/d at 177°C for 2 minutes.

[0031] As disclosed above, the polyester fiber of the present invention not only can have superior tenacity and properties but also can show superior performance in wear resistance and UV strength maintenance rate when it is prepared into the fiber rope, by securing the intrinsic viscosity, the initial modulus, and the elongation in the optimum range.

[0032] The monofilament fineness of the polyester fiber may be 21 DPF or less or 3 to 21 DPF, and preferably 20 DPF or less or 4 to 20 DPF. In order to use the polyester fiber to the marine rope or the industrial rope effectively, high denier is preferable in the aspect of the productivity and low denier is preferable in the aspect of the property exhibition, and thus the applicable total fineness of the polyester fiber may be 900 denier or more or 900 to 4,500 denier, and preferably 1,000 denier or more or 1,000 to 4,000 denier. Since the more number of the fiber filaments, the softer feel, but too many filaments are not good in the spinability and the wear resistance, the total number of the filaments may be 110 to 550, and preferably 120 to 550.

[0033] Furthermore, the polyester fiber may further include an additive with necessity in order to prevent the fiber damage during spinning, improve the friction resistance, and minimize the strength deterioration. Particularly, the polyester fiber, namely, the polyester raw fiber may include one or more inorganic additives selected from the group consisting of TiO_2, SiO_2, $BaSO_4$, and so on. At this time, the inorganic additive may be included with the content of 100 to 1,500 ppm, and preferably of 200 to 1,200 ppm, in the polyester fiber. The content of the inorganic additive may be 100 ppm or more, preferably 200 ppm or more, in the aspect of the spinability, and it may be 1,500 ppm or less, and preferably 1,200 ppm or less, in the aspect of the superior strength exhibition.

[0034] Meanwhile, the polyester fiber according to one embodiment disclosed above may be prepared by the method of preparing a polyester undrawn fiber by melt-spinning a polyester polymer and drawing the polyester undrawn fiber. As disclosed above, the concrete condition or the processing method of the steps is directly or indirectly reflected in the properties of the polyester fiber, and the polyester fiber having above properties can be prepared.

[0035] Particularly, it is revealed that the polyester fiber having the characteristic that the elastic recovery against the repetitive deformation is remarkably superior to the existing polyester fibers, namely, the characteristic that the recovered work ratio at the elongation corresponding to 10% of the maximum load measured at room temperature is 70% or more, the recovered work ratio at the elongation corresponding to 20% of the maximum load is 50% or more, and the recovered work ratio at the elongation corresponding to 30% of the maximum load is 40% or more, can be obtained through the process optimization disclosed above. Therefore, such polyester fiber can show the high recovered work ratio, the high strength, and the high elongation range at the same time, and it can be applied to the marine rope or the industrial rope having superior mechanical properties, a wear resistance, and a shock absorption performance preferably.

[0036] Each step of the preparation method of the polyester fiber is explained more in detail as follows.

[0037] The method of preparing the polyester fiber includes the steps of preparing a polyester undrawn fiber by melt-spinning a polyester polymer having an intrinsic viscosity of 1.2 dl/g or more at 270 to 310 °C, and drawing the polyester undrawn fiber.

[0038] First of all, the implementation of the melt spinning and drawing processes of the present invention can be explained briefly by referring the annexed figures, so that a person skilled in the related art to which the present invention pertains can easily carryout the same.

[0039] Fig. 1 is a schematic process drawing for representing the preparation process of the polyester fiber including the melt-spinning and drawing steps according to one embodiment of the present invention. As illustrated in Fig. 1, the present preparation method of the polyester fiber for the rope may include the processes of melting the polyester chip prepared by the method disclosed above, cooling the molten polymer spun through a die with quenching-air, providing a spinning oil to the undrawn fiber by using the oil rolls 120 (or oil-jets), and dispersing the spinning oil provided to the undrawn fiber uniformly on the surface of the fiber with uniform air pressure by using the pre-interlacer 130. Subsequently, the fiber may be prepared finally by intermingling the fiber with a uniform pressure in the second interlacer 150 and winding the same with the winder 160, after carrying out a drawing process through the multi-step drawing apparatuses 141 -146.

[0040] At first, the preparation method of the present invention prepares the polyester undrawn fiber by melt-spinning the high viscosity polymer including polyethylene terephthalate.

[0041] At this time, in order to obtain the polyester undrawn fiber satisfying low initial modulus and high elongation range, it is preferable to carry out the melt-spinning process at low temperature range so as to minimize the thermal degradation of the polyester polymer. Particularly, in order to minimize the deterioration of the intrinsic viscosity and the CEG (Carboxyl End Group) content of the high viscosity polyester polymer during the process, namely, in order to maintain the high intrinsic viscosity and the low CEG content of the polyester polymer, the melt-spinning may be carried out at low spinning temperature, for example, at the temperature of 270 to 310 °C, preferably of 280 to 305 °C, and more preferably of 282 to 298 °C. Here, the spinning temperature means the temperature of the extruder, and if the melt-spinning process is carried out at the temperature over 310 °C, it causes plentiful thermal degradations of the polyester fiber and the decrease of the intrinsic viscosity, the decrease in molecular weight and the increase in CEG content may get bigger, the surface of the fiber is damaged, and it may cause the deterioration of overall properties. On the contrary, if the melt-spinning process is carried out at the temperature below 270 °C, it may be difficult to melt the polyester polymer and the spinability may deteriorate due to N/Z surface cooling. Therefore, it is preferable to carry out the melt-spinning process within said temperature range. The polyester polymer preferably includes polyethylene terephthalate (PET) as the main component. At this time, various additives may be included with PET in the preparation process, and the fiber may include 70 mol% or more, preferably 90 mol% or more, of PET in order to secure the superior mechanical properties when it is made into the polyester fiber rope.

[0042] Furthermore, the polyester polymer may include one or more inorganic additives selected from the group consisting of TiO_2, SiO_2, $BaSO_4$, and so on with necessity. At this time, the inorganic additive may be included with the content of 100 to 1,200 ppm, and preferably of 200 to 1,000 ppm in the polyester fiber. The content of the inorganic additive may be 100 ppm or more, and preferably 200 ppm or more, in the aspect of spinability, and it may be 1,500 ppm or less, and preferably 1,200 ppm or less, in the aspect of superior strength exhibition.

[0043] As the results of experiments, it is revealed that, by carrying out the melt-spinning process of PET at such low temperature range, the degradation reaction of the polyester polymer is minimized so as to secure the high molecular weight and maintain the high intrinsic viscosity and the high strength fiber can be obtained without applying high drawing ratio in succeeding drawing process and since the drawing process can be carried out with low drawing ratio, the modulus can be lowered effectively and the polyester fiber satisfying the properties disclosed above can be obtained.

[0044] Furthermore, the melt-spinning process may be carried out with low spinning speed so as to carry out the process under lower spinning tension, namely, so as to minimize the spinning tension, in the aspect of minimizing the degradation reaction of the polyester polymer. For example, the melt-spinning speed of the polyester polymer may be controlled to be 300 to 1,000 m/min, and preferably to be 350 to 700 m/min. Since the melt-spinning process of the polyester polymer is carried out selectively under low spinning tension and low spinning speed, the degradation reaction of the polyester polymer can be minimized.

[0045] Meanwhile, the undrawn fiber obtained after the melt-spinning process may show the intrinsic viscosity of 0.8 dl/g or more or 0.8 dl/ g to 1.2 dl/g, preferably of 0.85 dl/g or more or 0.85 dl/ g to 1.2 dl/g, and more preferably or 0.9 dl/g or more or 0.90 dl/g to 1.2 dl/g.

[0046] Particularly, it is preferable to use the high viscosity polyester polymer, for example, the polyester polymer having the intrinsic viscosity of 1.2 dl/g or more, in the preparation process of the undrawn fiber, in order to prepare the high strength and low modulus polyester fiber, as disclosed above. And, it becomes possible to reveal the high strength with low drawing ratio and lower the modulus effectively by maintaining the high viscosity range to the maximum through the melt-spinning and drawing processes using the high viscosity polyester polymer. However, it is more preferable that the intrinsic viscosity is 2.0 dl/g or less in order to prevent the molecular chain scission caused by the temperature rise for melting the polyester polymer and the pressure increase by the discharge rate at the spinning pack.

[0047] And, it is preferable that the PET chip is spun through a spinning die designed for that the polyester fiber has the monofilament fineness of 21 DPF or less or 3 to 21 DPF, preferably of 20 DPF or less or 4 to 20 DPF. Namely, the monofilament fineness of the fiber is preferably 4.0 DPF or more in order to reduce the possibility of the fiber breaking during the spinning process or by the interference between the fibers during a cooling process, and the monofilament fineness is preferably 20 DPF or less in order to increase the cooling efficiency.

[0048] Furthermore, the process for preparing the PET undrawn fiber may further include a cooling process after the melt-spinning process of PET. Said cooling process is carried out preferably by providing a cooling air of 15 to 60 °C. At this time, the cooling air volume is controlled preferably to be 0.4 to 1.5 m/s in each temperature condition of the cooling air. With this, the PET undrawn fiber showing all the properties according to one embodiment of the present invention can be prepared more easily.

[0049] Meanwhile, after preparing the polyester undrawn fiber through such spinning step, the drawn fiber is prepared by drawing the undrawn fiber. At this time, the drawing process may be carried out with the total drawing ratio of 5.0 to 6.5, and preferably of 5.0 to 6.2. The polyester undrawn fiber is maintaining the high intrinsic viscosity and the low initial modulus by the optimized melt-spinning process. Therefore, if the drawing process is carried out with high drawing ratio over 6.5, a fiber breaking or hairiness may occur because it reaches an overdrawn level and the low elongation and high modulus fiber may be obtained due to the high orientation. Particularly, in the case of that the elongation of the fiber decreases and the modulus increases under the condition of high drawing ratio, the wear resistance and the strength maintaining rate may become not good when it is applied to the fiber rope. On the other hand, if the drawing process is carried out with relatively low drawing ratio, the strength of the polyester fiber prepared by the method may be lowered partially because the degree of orientation of the fiber is low. However, it is preferable in the aspect of the properties that the drawing process is carried out with the drawing ratio of 5.0 to 6.5, because it is possible to prepare the high strength and low modulus polyester fiber suitable to be applied to the marine or industrial fiber rope, for example, by carrying out the drawing process with the drawing ratio of 5.0 or more.

[0050] According to another preferable embodiment of the present invention, in order to prepare the low modulus polyester fiber with a direct spin-draw process while satisfying high strength and low shrinkage characteristic at the same time, the method may include a drawing process through the multi-step godet rollers, a heat-setting process, a relaxation process, after melt-spinning the high viscosity polyethylene terephthalate polymer chips and before winding the fiber on the winder.

[0051] The drawing process may be carried out after passing the undrawn fiber through the godet-rollers with 0.2% to 2.0% of oil pickup amount.

[0052] The relaxation ratio in the relaxation process is preferably 1% to 14%. If the relaxation ratio is below 1%, it is difficult to exhibit the shrinkage ratio and it may be difficult to prepare the high elongation low modulus fiber because of high degree of orientation of the fiber like in the high drawing ratio condition. If the relaxation ratio exceeds 14%, the fiber vibration intensifies on the godet rollers and it is difficult to secure the workability.

[0053] Furthermore, the heat-setting process that heat-treats the undrawn fiber at the temperature of about 170 to 250 °C may be carried out in the drawing process. At this time, the heat-setting process may be carried out preferably at the temperature of 175 to 240 °C, and more preferably at 180 to 245 °C. Here, if the temperature is below 170 °C, it may be difficult to achieve the shrinkage rate because the thermal effect is insufficient and the relaxation efficiency deteriorates. On the other hand, if the temperature exceeds 250 °C, the strength of the fiber may be deteriorated by thermal degradation and the workability may decrease because the tar formed on the roller increases.

[0054] At this time, the winding speed may be 2,000 to 4,000 m/min, and preferably 2,500 to 3,700 m/min.

[0055] Meanwhile, since the polyester fiber of the present invention shows the characteristics of high strength, high elongation, high recovered work ratio, it may be used preferably to the industrial materials for various uses such as the marine rope being used in anchoring, mooring, of towing a ship, or the industrial rope being used in various construction sites.

[0056] Particularly, the polyester fiber of the present invention may be made into the marine or industrial polyester fiber rope through a plaiting and twisting process. The fiber rope may be prepared by carrying out the plaiting and twisting process with one identical apparatus.

[0057] In the case of the fiber rope made of the polyester fiber of the present invention, the strength at break per unit diameter (mm) may be 0.67 ton/mm or more or 0.67 to 1.2 ton/mm, preferably 0.69 ton/mm or more, and more preferably 0.72 ton/mm or more. The elongation at break may be 18% or more or 18% to 45%, preferably 20 % or more, and more preferably 24% or more. The moisture absorption rate of the fiber rope may be 2% or less, preferably 1% or less, and more preferably 0.5% or less. The moisture absorption rate of the fiber rope is based on the value measured under the conditions of 25 °C and relative humidity of 65%RH. The strength maintenance of the fiber rope may be 90% or more, preferably 95% or more, and more preferably 98% or more. The strength maintenance rate of the fiber rope may be obtained by measuring the degree of strength decrease after wetting or UV irradiation.

[0058] For example, the degree of the strength decrease by wetting may be measured by carrying out the tensile test at room temperature immediately after wetting the fiber rope in the water of room temperature for 30 minutes. The strength maintenance after wetting of the fiber rope of the present invention may be 90% or more, preferably 95% or more, and more preferably 98% or more. Furthermore, the degree of strength decrease may also be measured after irradiating the fiber rope with xenon arc light at 40 °C and 65%RH for 100 hours. The strength maintenance after UV irradiation of the fiber rope of the present invention may be 90 % or more, preferably 95% or more, and more preferably 98 % or more.

[0059] The fiber rope made of the polyester fiber may have the recovered work ratio of 80% or more, preferably 85% or more, and more preferably 90% or more, at the elongation corresponding to 10% of the maximum load measured at room temperature. Furthermore, the fiber rope may have the recovered work ratio of 60% or more, preferably 61 % or more, and more preferably 62% or more, at the elongation corresponding to 20% of the maximum load. The fiber rope made of the polyester fiber of the present invention may have the recovered work ratio of 50% or more, preferably 51% or more, and more preferably 52% or more, at the elongation corresponding to 30 % of the maximum load.

[0060] At this time, the elastic recovery (recovered work ratio) of the polyester fiber rope may be the percentage value (%) of the recovered work per the total work in the stress-elongation graph obtained by the tensile test, as represented by the following Calculation Formula 2:

[Calculation Formula 2]

Elastic Recovery (Recovered Work Ratio) of Rope = {(Area of Recovered Work) / (Area of Total Work)} × 100

[0061] Here, the total work is the value corresponding to the area of the strength-elongation curve that is obtained by measuring the strength at break and the elongation at break of the rope at room temperature, as illustrated in Fig. 2. In above formula 2, the recovered work is the value corresponding to the area of the strength-elongation curve measured after repeating the elongation corresponding to 10%, 20%, or 30% of the maximum load respectively and the release 10 times, as illustrated in Fig. 2. In the marine rope for anchoring or mooring a ship, if the recovered work ratio of the fiber is low like the existing polyester fiber ropes, it cannot respond sufficiently to the deformation caused by the movement of the ship according to the change of the sea during anchoring the ship, and it loses the ability to hold the ship during anchoring the ship because it loses the elastic recovery after a period of use.

[0062] Since the polyester fiber rope of the present invention has the minimized moisture absorption rate in company with the superior elongation at break and the strength maintenance rate, the life of the rope can be extended and it becomes possible to secure sufficient stability for anchoring, mooring, towing a ship or in various construction sites, through the superior mechanical properties and the effective response to the change of external environment.

[0063] In the present invention, items besides above disclosure can be added or subtracted with necessity and the present invention does not limit them particularly.

EFFECTS OF THE INVENTION

[0064] According to the present invention, the polyester fiber having the superior wear resistance and strength maintenance rate in company with the superior mechanical properties is provided by optimizing the elastic recovery, the elongation at break and the strength to be a certain high level.

[0065] Such polyester fiber can have a sufficient strength and elongation, and can secure superior mechanical properties and shock absorption performance because it is optimized to have a high strength, a high elastic recovery, and a high elongation. By this, it becomes possible to prepare the rope which can minimize the fiber breaking, can improve the shock absorption performance noticeably, and can secure the superior life and the sufficient stability of the rope, even if there is a change of external environment such as the rough sea and the severe rolling of a ship.

[0066] Hereinafter, preferable examples and comparative examples are presented for understanding the present invention. However, the following examples are only for illustrating the present invention and the present invention is not limited to or by them.

Examples 1-5

[0067] After preparing a polyester undrawn fiber by the method of melt-sinning a polyester polymer having a certain intrinsic viscosity and cooling the same, a polyester fiber was prepared by drawing the undrawn fibers with a certain drawing ratio while heat-treating the same. At this time, the intrinsic viscosity of the polyester polymer, spinning speed and spinning tension in the melt-spinning process, spinning temperature condition, drawing ratio, heat-treating temperature followed the conditions in the follow Table 1, and the other conditions were dealt with in accordance with common conditions for preparing a polyester fiber.

[Table 1]

Classifications	Example 1	Example 2	Example 3	Example 4	Example 5
PET Content (mol%)	100	100	100	100	100
Intrinsic Viscosity of Chip (dl/g)	1.20	1.23	1.27	1.30	1.35
Spinning Temperature (°C)	285	286	288	290	292
Drawing Ratio	5.8	5.75	5.73	5.67	5.60
Heat-treatment Temperature (°C)	235	236	237	243	245

[0068] The properties of the polyester fibers prepared according to Examples 1-5 were measured according to the following methods, and the measured properties are listed in the following Table 2.

1) Tensile Strength and Elongation at Break

[0069] The tensile strength and the elongation at break of the polyester fibers were tested by using a universal testing machine (UTM) (INSTRON Ltd.) according to ASTM D 2256 method. At this time, the sample length was 250 mm, the straining speed was 300 mm/min, and the initial load was set-up to 0.05 g/d.

2) Elastic Recovery

[0070] After measuring the strength-elongation curve according to ASTM D 2256 method at room temperature and checking the maximum load and the total work, the strength-elongation curve was measured again and the recovered work was calculated after repeating the elongation corresponding to 10%, 20%,or 30% of the maximum load respectively and the release 10 times, and the recovered work ratio (%) of the fiber was calculated according to Calculation Formula 1:

[Calculation Formula 1]

Elastic Recovery (Recovered Work Ratio) of Fiber = {(Area of Recovered Work) / (Area of Total Work)} × 100

3) Dry Heat Shrinkage Rate

[0071] Dry heat shrinkage rate was measured by using a Testrite MK-V device (Testrite Co., UK) under the condition of providing the fixed load of 0.01 g/d at 177 °C for 2 minutes

4) Intrinsic Viscosity

[0072] After extracting the spinning oil from the specimen with carbon tetrachloride and dissolving the specimen in ortho-chlorophenol at 160±2°C, the viscosity of the specimen in a capillary was measured by using an automatic viscometer (Skyvis-4000) at the temperature of 25°C, and the intrinsic viscosity (IV) of the fiber was calculated according to the following Calculation Formula 3:

[Calculation Formula 3]

Intrinsic Viscosity (IV) = {(0.0242×Rel)+0.2634}× F

Rel = (seconds of solution × specific gravity of solution × viscosity coefficient) / (OCP viscosity)

F= IV of the standard chip / average of three IV measured from the standard chip with standard action

5) Fineness of Monofilament

[0073] After taking 9000m of the fiber bundle by using a bobbin, the fineness of monofilament was calculated by dividing the weight of the fiber bundle by the number of filaments.

[Table 2]

Classifications	Example 1	Example 2	Example 3	Example 4	Example 5
Intrinsic Viscosity of Fiber (dl/g)	0.85	0.88	0.92	0.97	1.01
Tensile Tenacity of Fiber (g/d)	9.2	9.3	9.2	9.4	9.4
Elongation at Break of Fiber (%)	16.3	17	17.5	18.2	19.5
Dry Heat Shrinkage Rate of Fiber (%)	5.0	5.5	5.8	5.4	5.0
Monofilament Fineness of Fiber (DPF)	12.5	10.4	13.0	12.5	10.4
Total Fineness of Fiber (de)	1,500	2,000	2,500	3,000	4,000
Recovered Work Ratio at 10% of Maximum Load (%)	88	91	94	97	99
Recovered Work Ratio at 20% of Maximum Load (%)	54	56	58	59	60
Recovered Work Ratio at 30% of Maximum Load (%)	40	41	43	44	46

Comparative Examples 1-5

[0074] The polyester fibers of Comparative Examples 1-5 were prepared substantially according to the same method as in Examples 1-5, except the conditions listed in the following Table 3.

[Table 3]

Classifications	Comparati ve Example 1	Comparati ve Example 2	Comparati ve Example 3	Comparati ve Example 4	Comparati ve Example 5
PET Content (mol%)	100	100	100	100	100
Intrinsic Viscosity of Chip (dl/g)	0.95	0.97	0.99	1.01	1.02

(continued)

Classifications	Comparati ve Example 1	Comparati ve Example 2	Comparati ve Example 3	Comparati ve Example 4	Comparati ve Example 5
Spinning Temperature (°C)	285	287	289	290	292
Drawing Ratio	6.23	6.20	6.18	6.15	6.13
Heat-treatment Temperature (°C)	210	213	215	218	220

[0075] The properties of the polyester fibers prepared according to Comparative Examples 1-5 are listed in the following Table 4.

[Table 4]

Classifications	Comparati ve Example 1	Comparati ve Example 2	Comparati ve Example 3	Comparati ve Example 4	Comparati ve Example 5
Intrinsic Viscosity of Fiber (dl/g)	0.60	0.65	0.70	0.85	0.88
Tensile Tenacity of Fiber (g/d)	7.7	8.4	8.8	9.0	9.5
Elongation at Break of Fiber (%)	14.3	12.5	12.7	13.7	11.5
Dry Heat Shrinkage Rate of Fiber (%)	9.0	9.8	9.6	9.0	8.9
Monofilament Fineness of Fiber (DPF)	3.7	2.8	3.9	52	52
Total Fineness of Fiber (de)	1,400	1,400	1,000	5,000	5,000
Recovered Work Ratio at 10% of Maximum Load (%)	64	65	65	68	64
Recovered Work Ratio at 20% of Maximum Load (%)	44	45	47	46	44
Recovered Work Ratio at 30% of Maximum Load (%)	39	39	36	37	35

[0076] Furthermore, Figs. 3 and 4 represent the strength-elongation curve of the polyester fibers according to Example 4 and Comparative Example 1 measured at room temperature. It is recognizable that the fiber of the present invention having long molecular chain (high viscosity) shows high strength and elongation and has high recovered work ratio as represented in Fig. 3, but the common polyester fiber of Comparative Example 1 shows remarkably deteriorated strength and elongation because of its low viscosity and short molecular chain length as represented in Fig. 4.

Preparation Examples 1-5

[0077] The polyester fibers prepared according to Examples 1-5 were made into the fiber ropes by applying S-twist in the first plaiting and Z-twist in the second plaiting. At this time, 7 ply of the fibers were S-twisted in the first plaiting, 4 ply of the S-twisted yarns were Z-twisted in the second plaiting, 16 ply of the plaited yarns were made into one strand, and 8 ply of the strands were made into the rope finally. The fiber ropes were prepared to have identical final fineness and the diameter of the ropes was 36mm.

[0078] The properties of the polyester fiber ropes prepared according to above method were measured by the following method.

a) Strength at Break and Elongation at Break

[0079] The strength at break and the elongation at break of the fiber rope were measured by the method of fixing both ends of the rope to loops and moving one loop with a speed of 1 m/min until the rope was broken.

b) Elastic Recovery

[0080] After checking the maximum load by measuring the strength at break and the elongation at break of the rope, the recovered work ratio (%) of the rope was calculated according to Calculation Formula 1 after repeating the elongation corresponding to 10%, 20%, or 30% of the maximum load respectively and the release 10 times:

[Calculation Formula 2]

Elastic Recovery (Recovered Work Ratio) of Rope = {(Area of Recovered Work) / (Area of Total Work)} × 100

c) Moisture Absorption Rate

[0081] The weight of the rope was measured at the condition of 25 °C and relative humidity of 65%RH. And then, the rope was dried at 100 °C for 6 hours by using a dryer and the weight of the rope was measured. The moisture absorption rate at 25 °C and 65%RH was calculated according to the following Calculation Formula 4:

[Calculation Formula 4]

Moisture Absorption Rate (%) = (Weight of Rope Before Drying – Weight of Rope After Drying) / (Weight of Rope After Drying) × 100

d) Strength Maintenance Rate after Wetting

[0082] Tensile test was carried out according to the same method as in above strength measurement immediately after wetting the rope in the water of room temperature for more than 30 minutes, and the strength maintenance rate after wetting was calculated according to the following Calculation Formula 5:

[Calculation Formula 5]

Strength Maintenance Rate after Wetting (%) = (Strength After Wetting) / (Strength Before Wetting) × 100

e) Strength Maintenance Rate after UV Irradiation

[0083] The strength of the fiber rope was measured according to the same method as in above strength measurement after irradiating the fiber rope with xenon arc light at 40 °C and 65%RH for 100 hours. The strength maintenance after UV irradiation was calculated according to the following Calculation Formula 6:

[Calculation Formula 6]

Strength Maintenance Rate after UV irradiation (%) = (Strength After UV irradiation) / (Strength Before UV irradiation) × 100

[0084] The properties of the fiber ropes of Preparation Examples 1-5 which were prepared by using the polyester fibers of Examples 1-5 are listed in the following Table 5.

[Table 5]

Classifications	Preparatio n Example 1	Preparatio n Example 2	Preparatio n Example 3	Preparatio n Example 4	Preparatio n Example 5
Strength at Break of Rope (Ton)	26.6	26.8	27.8	28.5	29.5
Elongation at Break of Rope (%)	23.5	24.6	25.3	26.1	27.4
Elastic Recovery at 10% of Maximum load (%)	93	95	97	99	100
Elastic Recovery at 20% of Maximum load (%)	63	66	74	70	78
Elastic Recovery at 30% of Maximum load (%)	53	58	64	66	71
Moisture Absorption Rate (%)	0.4	0.4	0.4	0.4	0.4

(continued)

Classifications	Preparatio n Example 1	Preparatio n Example 2	Preparatio n Example 3	Preparatio n Example 4	Preparatio n Example 5
Strength Maintenance Rate After Wetting (%)	100.1	99.8	99.9	100.3	100.5
Strength Maintenance Rate After UV irradiation (%)	99.5	99.9	99.6	99.7	99.5

Comparative Preparation Examples 1-5

[0085] The fiber ropes were prepared substantially according to the same method as in Preparation Examples 1-5, except that the polyester fibers of Comparative Examples 1-5 were used respectively. The properties are listed in the following Table 6.

Comparative Preparation Example 6

[0086] The fiber rope was prepared substantially according to the same method as in

[0087] Preparation Examples 1-5, except that the nylon fiber (1,700d, strength 9.0g/d, elongation 26%) was used. The properties are listed in the following Table 6.

[0088] The properties of the fiber ropes of Comparative Preparation Examples 1-6 which were prepared by using the polyester fibers of Comparative Examples 1-5 and nylon fiber are listed in the following Table 6.

[Table 6]

Classifications	Compa rative Prepara tion Exampl e1	Compa rative Prepara tion Exampl e2	Compa rative Prepara tion Exampl e3	Compa rative Prepara tion Exampl e4	Compa rative Prepara tion Exampl e5	Compa rative Prepara tion Exampl e6
Strength at Break (Ton)	22.0	23.8	24.3	24.0	24.5	28.3
Elongation at Break (%)	13.5	13.6	14.4	15.2	15.8	32.4
Elastic Recovery at 10% of Maximum load (%)	74	77	78	75	78	85
Elastic Recovery at 20% of Maximum load (%)	54	57	58	55	458	61
Elastic Recovery at 30% of Maximum load (%)	45	47	46	48	49	53
Moisture Absorption Rate (%)	0.4	0.4	0.4	0.4	0.4	4.2

(continued)

Classifications	Compa rative Prepara tion Exampl e1	Compa rative Prepara tion Exampl e2	Compa rative Prepara tion Exampl e3	Compa rative Prepara tion Exampl e4	Compa rative Prepara tion Exampl e5	Compa rative Prepara tion Exampl e6
Strength Maintenance Rate After Wetting (%)	97.5	97.4	97.6	97.7	97.1	74.9
Strength Maintenance Rate After UV irradiation (%)	96.2	96.4	96.8	97.2	97.5	74.3

[0089] As shown in Table 5, it is recognizable that the fiber ropes of Preparation Examples 1-5 made of the polyester fibers of Examples 1-5 having the high elastic recovery show very superior properties, namely, the strength at break of 26.6 ton to 29.5 ton and the elongation at break of 23.5% to 27.4%. At the same time, it is also recognizable that the fiber ropes of Preparation Examples 1-5 show very low level of moisture absorption rate at 25°C and 65%RH and very superior strength maintenance rate after wetting and strength maintenance rate after UV irradiation, for example, the moisture absorption rate at 25°C and 65%RH is about 0.4%, the strength maintenance rates after wetting is 99.8% to 100.5%, and the strength maintenance rates after UV irradiation is 99.5% to 99.9%. By this, it is recognizable that the fiber ropes of Preparation Examples 1-5 have superior light resistance, hydration resistance, wear resistance, low moisture absorption rate, shock absorption performance, and the like in company with the superior mechanical properties.

[0090] On the other hand, as shown in Table 6, it is recognized that the fiber ropes of Comparative Preparation Examples 1-5 made of the polyester fibers of Comparative Examples 1-5 do not satisfy such characteristics. Particularly, it is recognizable that the strength at break of the ropes of Comparative Preparation Examples 1-5 is merely 22.0 ton to 24.5 ton, the elongation at break is merely 13.5% to 15.8%, and thus the toughness of the fiber rope is markedly inferior. If the toughness of the fiber rope is inferior like this, it may be impossible to secure the mechanical properties sufficient for anchoring or mooring a ship or for construction sites.

[0091] Furthermore, it is recognized that the fiber rope of Comparative Preparation Example 6 made of nylon fiber, one of common synthetic fiber, has markedly inferior properties, for example, the moisture absorption rate at 25°C and 65%RH is 4.2%, the strength maintenance rates after wetting is 74.3% and the strength maintenance rates after UV irradiation is 74.9%. If the strength maintenance is inferior like this, it may cause a problem of that the mechanical properties decrease rapidly under the rough environment condition of the dockside for anchoring a ship.

Claims

1. A polyester fiber, wherein the recovered work ratio at the elongation corresponding to 10% of the maximum load measured at room temperature is 70% or more, the recovered work ratio at the elongation corresponding to 20% of the maximum load is 50% or more, and the recovered work ratio at the elongation corresponding to 30% of the maximum load is 40 % or more.

2. The polyester fiber according to Claim 1, wherein the total fineness is 900 denier or more.

3. The polyester fiber according to Claim 1, wherein the fineness of monofilament is 21 DPF or less and the total number of the filaments is 110 to 550.

4. The polyester fiber according to Claim 1, wherein the tensile tenacity is 8.8 d or more and the elongation at break is 15 % or more.

5. A method of preparing the polyester fiber according to any one of Claims 1 to 4, including the steps of:

   preparing a polyester undrawn fiber by melt-spinning a polyester polymer having an intrinsic viscosity of 1.2 dl/g or more at 270 to 310 °C, and
   drawing the polyester undrawn fiber.

6. The method according to Claim 5, wherein the polyester polymer includes 70 mol% or more of polyethylene terephthalate.

7. The method according to Claim 5, wherein the drawing step is carried out with the drawing ratio of 5.0 to 6.5.

8. The method according to Claim 5, further including a heat-setting process of the temperature of 170 to 250 °C after the drawing step.

9. The method according to Claim 5, further including a relaxation process of the relaxation ratio of 1% to 14% after the drawing step.

10. A polyester fiber rope, including the polyester fiber according to any one of Claims 1 to 4.

11. The polyester fiber rope according to Claim 10, wherein the strength at break per unit diameter (mm) is 0.67 ton/mm or more.

12. The polyester fiber rope according to Claim 10, wherein the elongation at break is 18 % or more.

13. The polyester fiber rope according to Claim 10, wherein the strength maintenance rate is 90 % or more.

14. The polyester fiber rope according to Claim 10, wherein the moisture absorption rate is 2% or less.

Fig. 1

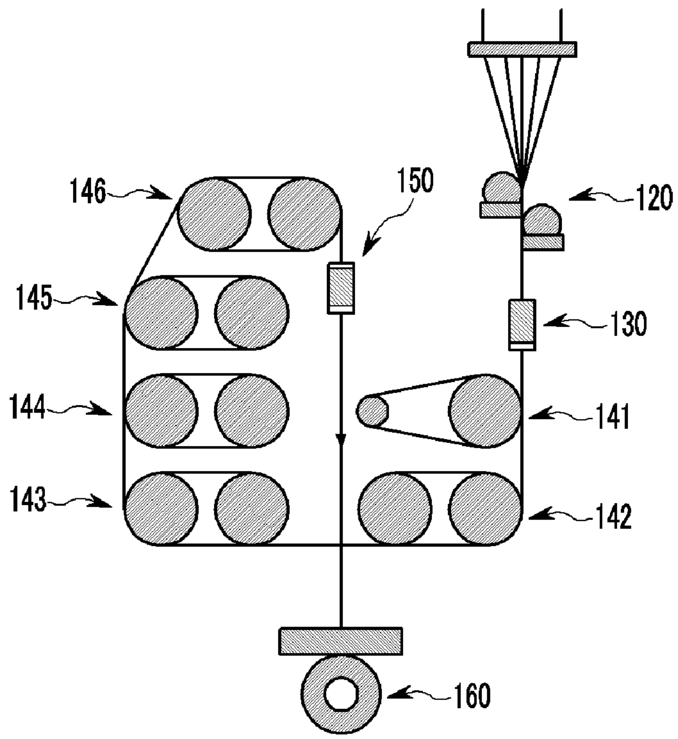


Fig. 2

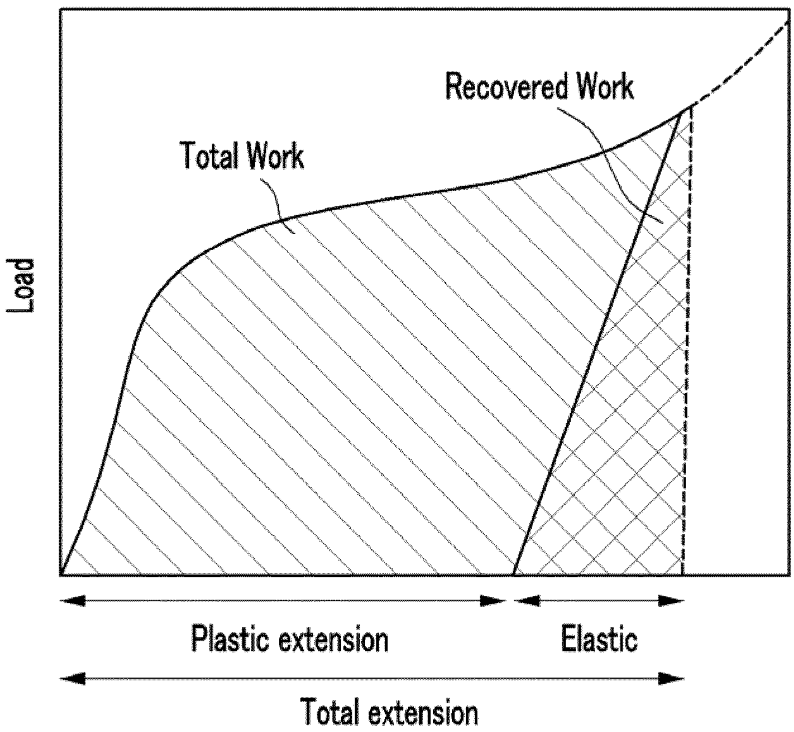
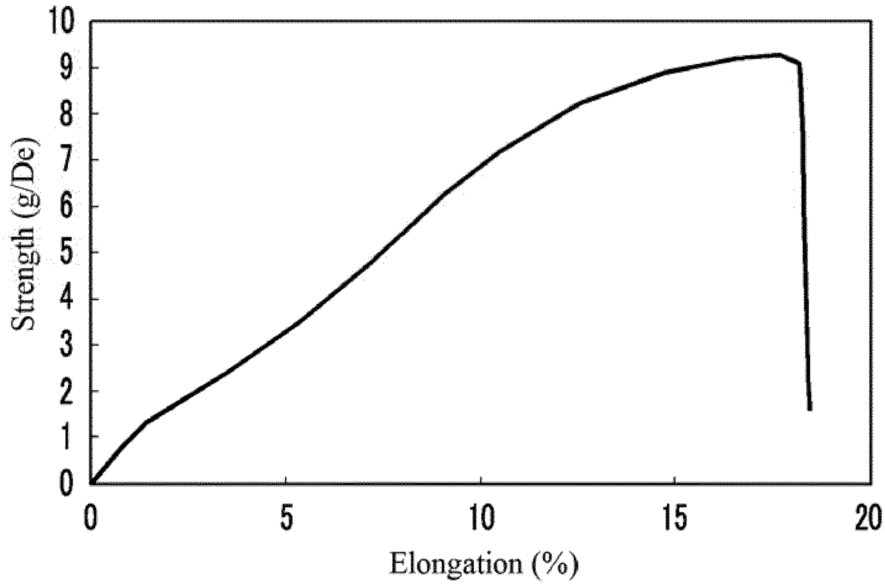

Recovered Work
Total Work
Load
Plastic extension
Elastic
Total extension

Fig. 3


Strength (g/De)
Elongation (%)
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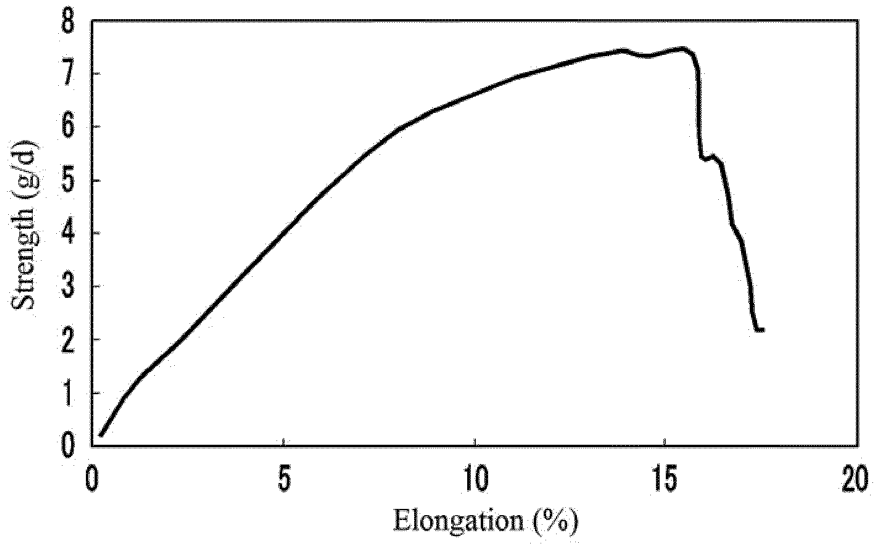
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20

Fig. 4


Strength (g/d)
Elongation (%)
0
1
2
3
4
5
6
7
8
0
5
10
15
20