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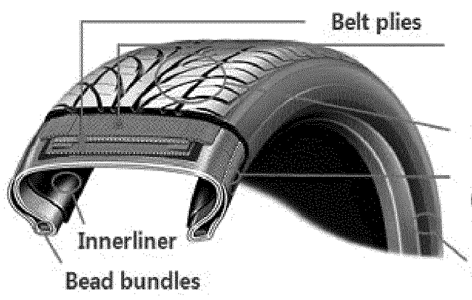
(54) POLY(ETHYLENETEREPHTHALATE) DRAWN FIBER, TIRE-CORD, AND METHOD OF MANUFACTURING THE POLY(ETHYLENETEREPHTHALATE) DRAWN FIBER AND THE TIRE-CORD

(57) The present invention relates to a drawn poly (ethyleneterephthalate) (PET) fiber exhibiting excellent dimensional stability and uniform properties while having high fineness of 2000 denier or more, a tire cord, and their preparation method.

The drawn PET fiber includes PET 90 mol% or more, and has a crystallinity of 40 to 50%, an amorphous orientation factor (AOF) of 0.01 to 0.2, a monofilament fineness of 2.5 to 4.0 denier, a coefficient of variation (CV) of cross sectional area of 8.0 % or less, and a total fineness of 2000 to 4000 denier.

Fig. 1



EP 2 660 370 A2

Description

TECHNICAL FIELD

[0001] The present invention relates to a drawn poly(ethyleneterephthalate) fiber exhibiting excellent dimensional stability and uniform properties while having high fineness of 2000 denier or more, a tire cord, and their preparation method.

BACKGROUND OF THE ART

[0002] Tire is a complex body of fiber/steel/rubber, and generally has a structure as illustrated in Fig. 1. Here, body ply, called as carcass, is a cord layer included in the tire as its core reinforcement which supports whole load of a car and stands against a shock for maintaining shape of the tire, and it requires good fatigue resistance against bending and stretching movement during a driving. In such body ply, namely tire cord, synthetic fiber materials of polyesters such as poly(ethyleneterephthalte) have been used generally.

[0003] The cord made of synthetic fibers has contributed to the durability improvement of tire with its high tenacity but it has a problem of decreasing the elasticity and dimensional stability after vulcanization of tire because of its high shrinkage rate by heat. To remedy this, an additional process such as post cure inflatation (PCI) has been suggested in order to improve the dimensional stability of cord but the effect was not enough.

[0004] Recently, an ultrahigh speed spinning technology is grafted onto the preparation method of tire cord, and it becomes possible to prepare a polyester tire cord having high modulus low shrinkage (HMLS) property without the PCI process.

[0005] However, in order to apply the ultrahigh speed spinning technology, it is necessary to use an undrawn fiber having high crystallinity. However, the undrawn fiber having high crystallinity has relatively narrow drawing range, and thus the fiber can be easily broken by uneven drawing or friction when it is applied to the ultrahigh speed spinning technology. On this account, when the undrawn fiber having high crystallinity is used in the ultrahigh speed spinning system, there is a limitation of drawing ratio and the fiber cannot be drawn sufficiently and the tensile strength of the drawn fiber may be largely deteriorated. Particularly, it is difficult to secure enough distance between orifices of spinneret and a cooling uniformity in the preparation processes of a drawn fiber having high fineness of 2000 denier or more and a tire cord including the same, and thus the properties such as tenacity decrease much more and it becomes difficult to obtain a tire cord having uniform properties.

[0006] In order to resolve this problem, a method of co-twisting the fibers during a drawing process after forming undrawn fibers of low fineness by an ultrahigh speed spinning technology was considered, but such co-twisting method has many difficulties in exhibiting a sufficient tenacity and an improved productivity based on high denier, because it costs too much and the tenacity gets damaged by friction during the co-twisting process. Moreover, even though such co-twisting method is used, it is not easy to obtain a drawn fiber and a tire cord having sufficiently uniform properties.

[0007] As the use of radial tire grows recently, a tire cord having excellent and uniform properties as well as high fineness is required. However, it does not meet such demands because of the problems disclosed above. Therefore, it has been continuously required to develop a technology for a drawn PET fiber having high fineness of 2000 denier or more while exhibiting excellent strength and dimensional stability and uniform properties, and a tire cord made of the same.

DETAILED DESCRIPTION OF THE INVENTION

TECHNICAL OBJECTIVES

[0008] An aspect of the present invention is to provide a drawn PET fiber having high fineness of 2000 denier or more while exhibiting excellent dimensional stability and uniform properties, and a method of preparing the same.

[0009] Another aspect of the present invention is to provide a PET tire cord having high fineness while exhibiting uniform properties and excellent dimensional stability, and a method of preparing the same.

[0010] The present invention provides a drawn poly(ethyleneterephthalate) (PET) fiber, including 90 mol% or more of PET and having a crystallinity of 40 to 50%, an amorphous orientation factor (AOF) of 0.01 to 0.2, a monofilament fineness of 2.5 to 4.0 denier, a coefficient of variation (CV) of cross sectional area of 8.0 % or less, and a total fineness of 2000 to 4000 denier.

[0011] The present invention also provides a method of preparing a drawn PET fiber, including the steps of melt-spinning a polymer including 90 mol% or more of PET through a spinneret by 3-ply or 4-ply co-spinning method so as to prepare an undrawn PET fiber having a fineness of 2000 denier or more, wherein the spinning speed is 2500 to 4000 m/min, and drawing the undrawn fiber with a drawing ratio of 1.4 to 2.0.

[0012] The present invention also provides a method of preparing a PET tire cord, including the steps of preparing a drawn PET fiber according to the method disclosed above, co-twisting the drawn fibers so as to prepare a twisted yarn;

and dipping the twisted yarn in an adhesive solution and heat-treating the same.

[0013] The present invention also provides a PET tire cord, having a total fineness of 4000 to 8000 denier, a tensile strength of 7.2 to 8.5 g/d, a dimensional stability index (E-S index) of 5.0 to 7.0 %, wherein the E-S index is the sum of a dry heat shrinkage rate after heat-treatment at 177 °C for 2 min under the load of 0.01 g/d and an intermediate elongation (@ 2.25 g/d load).

[0014] Hereinafter, the drawn PET fiber, the tire cord, and the preparing methods thereof according to the specific embodiments of the present invention are explained in more detail. However, since the embodiments are provided as examples of the present invention, the scope of the right of the present invention is not limited to or by them and it is obvious to a person skilled in the related art that various modifications of the embodiments are possible within the scope of the right of the present invention.

[0015] In addition, the term 'include' or 'comprise' means that include any component (or any element) without particular limitations unless otherwise mentioned in the present entire disclosure, and it cannot be interpreted as it excludes the addition of the other components (or elements).

[0016] The PET tire cord may be prepared as a dip cord type by melt-spinning a PET polymer so as to prepare an undrawn fiber, drawing the undrawn fiber so as to obtain a drawn fiber, co-twisting the PET drawn fibers and dipping the same into the adhesive. Therefore, the characteristics of the undrawn fiber prepared by melt-spinning the PET and the drawn fiber prepared by drawing the same are directly or indirectly reflected to the properties of the PET tire cord.

[0017] The present inventors has repeated a study of a drawn fiber for tire cord and completed the present invention by finding out that a drawn PET fiber exhibiting excellent strength and dimensional stability and uniform properties while having high fineness of 2000 denier or more can be provided by applying an ultrahigh speed spinning technology in company with a multi-ply co-spinning method such as 3-ply or 4-ply co-spinning, and a PET tire cord exhibiting excellent dimensional stability and uniform properties while having high fineness can be obtained from the same.

[0018] According to one embodiment of the present invention, a drawn PET fiber having specific characteristics is provided. Said drawn PET fiber may include 90 mol% or more of PET and may have a crystallinity of 40 to 50%, an amorphous orientation factor (AOF) of 0.01 to 0.2, a monofilament fineness of 2.5 to 4.0 denier, a coefficient of variation (CV) of cross sectional area of 8.0 % or less, and a total fineness of 2000 to 4000 denier.

[0019] At first, the PET polymer constituting the drawn fiber may include various additives which are included in the preparation processes thereof, and it is preferable that 90 mol% or more of PET is included in the polymer in order to show the properties of PET suitable for tire cord. Hereinafter, therefore, the term "PET" means that 90 mol% or more of PET polymer is included in the polymer unless otherwise explained.

[0020] The drawn PET fiber of one embodiment may be prepared under the controlled melt-spinning conditions and drawing conditions disclosed below by applying an ultrahigh speed spinning technology. According to this, the drawn PET fiber of one embodiment can exhibit a crystallinity of 40 to 50% and an AO F of 0.01 to 0.2.

[0021] Basically, the PET polymer constituting the drawn fiber has partially crystallized structure and is composed of crystalline regions and amorphous regions. However, the degree of crystallization of the drawn PET fiber obtained under the controlled melt-spinning conditions is higher than that of former known drawn PET fiber because of the oriented crystallization phenomenon, and it shows high crystallinity of 40% or more, for example 25 to 40 %. Therefore, the drawn PET fiber and the tire cord can show high modulus and high dimensional stability because of such high crystallinity.

[0022] At the same time, the drawn PET fiber shows an AOF of 0.20 or less, for example 0.01 to 0.2, which is largely lower than that of former known drawn fiber. The AOF means that the degree of orientation of the chains included in the amorphous region of the drawn fiber, and it decreases as the entanglement of the chains in the amorphous region increases. Generally, when the AOF decreases, the degree of disorder increases and the chains of the amorphous region become not a strained structure but a relaxed structure, and thus the drawn fiber and the tire cord show low shrinkage stress. However, the drawn PET fiber obtained under the controlled melt-spinning conditions includes more cross-linking bonds per a unit volume, because the molecular chains constituting the drawn PET fiber slip during the spinning process and form a fine network structure. On this account, the drawn PET fiber may become the structure of which the chains of the amorphous region are strained in spite of the largely lower AOF value, and it can show a developed crystalline structure and superior orientation characteristics due to this.

[0023] Consequently, the drawn fiber of one embodiment can show higher shrinkage stress, and can show more improved modulus and excellent dimensional stability due to this.

[0024] The drawn fiber of one embodiment is controlled to have a monofilament fineness of 2.5 to 4.0 while having very large total fineness of 2000 denier or more, for example 2000 to 4000 denier, and can exhibit a CV of cross sectional area of 8.0 % or less, for example 2.5 to 7.5 %, because it is prepared by 3-ply or 4-ply co-spinning method as disclosed below.

[0025] At this time, the CV of cross sectional area is called as the value of the standard deviation of cross sectional area of each fiber constituting the drawn fiber divided by the arithmetic mean, and the CV of cross sectional area of 8.0 % or less means that each fiber constituting the drawn fiber has very uniform cross sectional area. Therefore, the drawn fiber of one embodiment can exhibit very uniform properties while having high fineness.

[0026] Finally, the drawn fiber of one embodiment can exhibit excellent dimensional stability and uniform properties while having high fineness of 2000 denier or more, and thus it becomes possible to provide a PET tire cord which can be preferably applied as a body ply of radial tire to which high fineness is required.

[0027] The drawn PET fiber of one embodiment may have a tensile strength of 8.0 to 9.5 g/d, and preferably 8.0 to 9.3 g/d, and an intermediate elongation (@ 4.5 g/d load) of 4.0 to 6.5 %, and preferably 4.5 to 5.5%. And, the drawn PET fiber may have a breaking elongation of 12.0 to 20.0 %, and preferably 13.0 to 18.0%.

[0028] Prior known drawn PET fibers had limitations to exhibit excellent and uniform properties and high tenacity, because there was a limit to apply high drawing ratio and the tenacity deterioration was caused by a friction between fibers and an uneven cooling, when they were prepared to have high fineness by applying the ultrahigh speed spinning technology. However, the drawn fiber of one embodiment is prepared by applying the ultrahigh speed spinning conditions and 3-ply or 4-ply co-spinning method as disclosed below, and thus it can exhibit excellent tenacity and other properties as disclosed above. Therefore, the drawn PET fiber can satisfy the requirement of the field trying for the tire cord having high fineness while exhibiting excellent properties, and can be used most preferably for providing a tire cord for various applications such as a body ply or a cap ply.

[0029] Meanwhile, according to another embodiment of the present invention, a preparation method of said drawn PET fiber is provided. The preparation method of the drawn PET fiber may include the steps of melt-spinning a polymer including 90 mol% or more of PET through a spinneret by 3-ply or 4-ply co-spinning method so as to prepare an undrawn PET fiber having a fineness of 2000 denier or more, wherein the spinning speed is 2500 to 4000 m/min; and drawing the undrawn fiber with a drawing ratio of 1.4 to 2.0.

[0030] The preparation method uses an ultrahigh speed spinning condition to which a melt-spinning speed of 2500 m/min or more is applied, and the drawn PET fiber having high crystallinity and low AOF can be prepared by using the ultrahigh speed spinning condition. The technical principle can be predicted as follows.

[0031] The undrawn fiber prepared through the ultrahigh speed spinning condition may exhibit a crystallinity of 10 to 30 % and low AOF of 0.08 to 0.2.

[0032] The PET polymer constituting the undrawn fiber has partially crystallized structure and is composed of crystalline regions and amorphous regions. However, the degree of crystallization of the undrawn fiber obtained by the ultrahigh speed spinning condition is higher than that of former known undrawn fiber (generally, crystallized below 7.0 %) because of the oriented crystallization phenomenon, and the crystallinity may be 10% or more, and preferably 10 to 30%.

[0033] At the same time, the undrawn fiber may show an AOF of 0.2 or less, and preferably 0.08 to 0.2, which is much lower than that of former known undrawn fiber, because of the oriented crystallization phenomenon. In addition, the undrawn fiber may include more cross-linking bonds per a unit volume, because the molecular chains constituting the undrawn fiber slip during the spinning process and form a fine network structure.

[0034] Owing to the crystalline characteristics of the undrawn fiber, the drawn fiber obtained therefrom also can exhibit high crystallinity and low AOF value as disclosed above and makes it possible to provide a drawn fiber and a tire cord having excellent dimensional stability.

[0035] Meanwhile, in the preparation method of said another embodiment, 3-ply or 4-ply co-spinning method is used in company with the ultrahigh speed spinning condition so as to prepare the drawn PET fiber. In this case, the discharge rate of the polymer to be cooled in one spinning chimney becomes relatively low, the fiber entanglement caused by interference between the fibers by cooling air can be suppressed, and it becomes possible to overcome the limitation of the number of spinning orifices according to the limited area of spinneret, and thus it becomes possible to secure low fineness of monofilament, for example 2.5 to 4.0 denier, which is essential for high strength and excellent dimensional stability. Therefore, even if the ultrahigh speed spinning technology is used, whole discharged polymer can be cooled uniformly and the cooling efficiency can be largely improved. According to this, when the drawn fiber is prepared by the sequential steps of: cooling the discharged polymer, preparing the undrawn fiber by joining the cooled product together, and preparing the drawn fiber having high fineness of 2000 denier or more by drawing the undrawn fiber, the advantage of the ultrahigh speed spinning technology can be reflected to the fiber and it becomes possible to provide the drawn PET fiber having uniform properties and cross sectional area in addition to excellent strength and dimensional stability effectively while minimizing the deterioration of properties such as tenacity.

[0036] Furthermore, the performance and effect according to the application of ultrahigh speed spinning technology can be preferably maintained by the application of 3-ply or 4-ply co-spinning method. Therefore, said high crystallinity and low AOF of the drawn fiber can be properly appeared during the preparation of the drawn fiber of high fineness, and the drawn fiber and the tire cord having more excellent dimensional stability can be provided.

[0037] In comparison, when 1-ply or 2-ply co-spinning method is used for preparing a drawn fiber having high fineness, uneven or insufficient cooling may occur because the excess discharged polymer stays in the spinning chimney and the distance between the spinning orifices is short, and the monofilaments between inside and outside of spinneret may have large deviation in properties and cross sectional area. Therefore, it is difficult to prepare the drawn PET fiber of one embodiment having uniform properties and cross sectional area according to this method. And, it is undesirable to increase the flowing speed and amount of cooling air in order to resolve said problem of 2-ply co-spinning method because it may cause a fiber breaking or property decrease. And, if a multi-ply co-spinning method over 4-ply is used, it is difficult to secure production efficiency. In addition to, when 1-ply or 2-ply co-spinning method is used for preparing a drawn fiber having high fineness, it is difficult to exhibit the performance and effect according to the application of ultrahigh speed spinning technology, and it would be difficult to achieve low AOF of the drawn fiber. Therefore, the dimensional stability of the drawn fiber and the tire cord may be deteriorated.

[0038] Therefore, the drawn PET fiber satisfying the properties of one embodiment can be prepared at last by using the preparation method of said another embodiment, and the drawn fiber exhibits excellent strength and outstanding dimensional stability and has uniform properties and cross sectional area while having high fineness. According to this, a tire cord having excellent and uniform properties and outstanding dimensional stability while having high fineness can be provided, and such PET tire cord can be used very suitably to a body ply of pneumatic tire, particularly to a tire cord requiring high fineness.

[0039] Hereinafter, the preparation method of the drawn PET fiber is explained step by step in more detail.

[0040] In the preparation method, firstly, an undrawn fiber is prepared by melt-spinning a PET polymer by 3-ply or 4-ply co-spinning method.

[0041] As the ultrahigh speed spinning technology is used in the step of preparing the undrawn fiber, the undrawn fiber having high crystallinity is obtained and a drawn fiber and a tire cord exhibiting excellent strength and dimensional stability can be prepared through succeeding processes using the same. In order to obtain the undrawn fiber of such high crystallinity, the polymer is melt-spun with a spinning speed of 2500 to 4000m/min, and preferably 3500 to 4000 m/min. Namely, it is preferable to apply the spinning speed of 2500 m/min or more for securing the properties of the undrawn fiber such as high crystallinity or the productivity, and it is preferable to apply the spinning speed of 4000 m/min or less for giving minimum cooling time required in the undrawn fiber preparation.

[0042] Furthermore, the melt-spinning of the polymer is carried out preferably under the spinning tension of 0.5 to 1.2 g/d. Namely, it is preferable that the spinning tension is 0.5 g/d or more in order to obtain the properties of the undrawn fiber required in the present invention, for example high crystallinity and the like, and it is preferable that the spinning tension is 1.2 g/d or less in order to prevent the filament break or the property deterioration due to an excessive tension.

[0043] And, the intrinsic viscosity (IV) of the PET polymer may be 0.8 to 1.5 dl/g, and preferably 1.2 to 1.5 dl/g, in order to prepare the undrawn fiber with the spinning speed and the spinning tension disclosed above. The strength of the drawn fiber and the tire cord can be improved much more by using the polymer having relatively high IV and applying the ultrahigh speed spinning technology. However, it is preferable that the polymer having an IV of 1.5 dl/g or less is melt-spun, in order to suppress the fiber break due to an excessive increase of the pressure in the spinning pack.

[0044] Meanwhile, the undrawn fiber may be prepared by adding a cooling process after melt-spinning the PET polymer with above conditions, and the cooling process is preferably carried out with a method of providing a cooling air of 15 to 60 °C, and the rate of cooling air is preferably controlled to be 0.4 to 1.5 m/s in each temperature condition of the cooling air.

[0045] Furthermore, the uniform cooling becomes possible because the 3-ply or 4-ply co-spinning method is applied in company with the melt-spinning conditions disclosed above, and a drawn fiber of high fineness exhibiting uniform properties and cross sectional area and a tire cord can be obtained while the property deterioration is minimized during the preparation process, as disclosed above. Such uniform property and cross sectional area are due to the uniform cross sectional area of the undrawn fiber obtained by the uniform cooling, and the undrawn fiber prepared by said process may have a CV of cross sectional area of 8.0 % or less.

[0046] After preparing the undrawn fiber as disclosed above, a drawn PET fiber is prepared by drawing the undrawn fiber. The drawing step may be carried out with a direct spinning & drawing (DSC) method in which the spinning and the drawing are continuously carried out in one process according to a conventional process of preparing a drawn fiber.

[0047] And, the drawing ratio in the drawing step is preferably 1.4 to 2.0 times. Namely, the drawing ratio is preferably 1.4 times or more in order to prepare a tire cord having excellent strength and dimensional stability, and it is preferably 2.0 times or less because there is a limitation of the drawing ratio control in the ultrahigh speed spinning system and the orientation and the crystallinity of the undrawn fiber increase due to the fineness decrease of monofilament caused by the application of high-multi filament method.

[0048] A drawn fiber having the total fineness of 2000 to 4000 denier can be prepared by the drawing step. At this time, the fineness of monofilament is 2.5 to 4.0 denier preferably. The fineness of monofilament is 2.5 denier or more preferably, in order to give the prepared drawn fiber the drawing ratio required for exhibiting the properties suitable for a tire cord and to prevent the fiber entanglement by the cooling air. And, the fineness of monofilament is 4.0 denier or less preferably, in order to give the polymer discharged through the spinneret the uniform cooling by the cooling air and to improve the dimensional stability of the tire cord product by reducing the discharge rate of the polymer for increasing the spinning tension.

[0049] Meanwhile, according to still another embodiment of the present invention, a method of preparing a PET tire cord using the preparation method of the drawn PET fiber disclosed above is provided. The preparation method of a PET tire cord may include the steps of preparing a drawn PET fiber according to the method disclosed above; co-twisting the drawn fibers so as to prepare a twisted yarn; and dipping the twisted yarn in an adhesive solution and heat-treating the same.

[0050] In the preparation method of a tire cord, for example, the co-twisting step may be carried out by 'Z' twisting the drawn fiber having a total fineness of 2000 to 4000 denier with a twisting level of 100 to 400 TPM (twist per meter), and 'S' twisting 1 to 3 ply of the 'Z' twisted fibers with a twisting level of 100 to 400 TPM so as to prepare a co-twisted yarn having a total fineness of 4000 to 8000 denier.

[0051] Furthermore, an adhesive solution which is conventionally used for preparing a tire cord, for example resorcinol-formaldehyde-latex (RFL) adhesive solution, may be used as the adhesive solution. And the heat-treating process may be carried out at the temperature of 230 to 260 °C for 90 to 360 sec, preferably at the temperature of 240 to 250 °C for 90 to 240 sec, and more preferably at the temperature of 245 to 250 °C for 90 to 120 sec.

[0052] The tire cord may be prepared through above method. However, said each step is just one example of the preparation method of a tire cord, and any step which can be commonly carried out in the art to which the present invention pertains may be included before or after above steps, of course.

[0053] The tire cord prepared according to such process may have high fineness such as a total fineness of 4000 to 8000 denier, and may show a tensile strength of 7.2 to 8.5 g/d and a dimensional stability index (E-S index) of 5.0 to 7.0 %, wherein the E-S index is the sum of a dry heat shrinkage rate after heat-treatment at 177 °C for 2 min under the load of 0.01 g/d and an intermediate elongation (@ 2.25 g/d load). At this time, the 'dimensional stability index (E-S index)' is represented by the sum of the 'dry heat shrinkage rate (after 2 min at 177 °C under the load of 0.01 g/d)' and the 'intermediate elongation (@ 2.25 g/d load)', the lower E-S index represents smaller dimensional deformation and superior tensile strength of the tire cord. And the tire cord may exhibit the properties such as an intermediate elongation (@ 2.25 g/d load) of 3.0 to 5.5 % and a breaking elongation of 15.0% or more, and suitably 15.0 to 17.0 %.

[0054] As disclosed above, the tire cord prepared according to said process is prepared by applying the ultrahigh speed spinning technology and 3-ply or 4-ply co-spinning method together, and it can exhibit excellent tensile strength and outstanding dimensional stability while having high fineness and can show uniform general properties. Therefore, the tire cord can be very preferably applied to a body ply of a pneumatic tire and can support whole load of a car very effectively. However, the use of the tire cord is not limited to this and it can be applied to other uses such as a cap ply and the like, of course.

ADVANTAGEOUS EFFECT OF THE INVENTION

[0055] According to the present invention, a tire cord having superior dimensional stability and strength and uniform properties while having high fineness and a preparation method thereof can be provided. Such tire cord is preferably used to a body ply of a pneumatic tire and can improve controllability and riding comport of a car.

BRIEF DESCRIPTION OF THE DRAWINGS

[0056]

Fig. 1 is a partial cut-away perspective view illustrating a structure of a general tire.

DETAILS FOR PRACTICING THE INVENTION

[0057] Hereinafter, preferable examples are provided for the understanding of the present invention. However, the following examples are only for exemplifying the present invention and the present invention is not limited to or by them.

[Preparation of drawn fibers]

Examples 1 to 6 (preparation of drawn PET fibers of 2000 denier or more to which 3-ply or 4-ply co-spinning method and ultrahigh speed spinning technology are applied)

[0058] The undrawn PET fibers of Examples 1 to 6 were prepared by the method of melt-spinning PET polymer chips and cooling the same according to the ultrahigh speed spinning technology to which 3-ply or 4-ply co-spinning method was applied. At this time, the conditions used in the spinning process were same as listed in the following Table 1, and the other conditions followed common conditions for preparing an undrawn PET fiber. And the drawn PET fibers were prepared by drawing the undrawn fibers with specific drawing ratios listed in Table 1, and heat-treating and winding the same.

Comparative Examples 1 to 5 (preparation of drawn PET fibers of 2000 denier or more to which 1-ply or 2-ply co-spinning method and ultrahigh speed spinning technology are applied)

[0059] By contrast to Examples 1 to 6, the drawn PET fibers were prepared according to the ultrahigh speed spinning technology to which 1-ply or 2-ply co-spinning method was applied. The conditions used in the spinning are listed in the following Table 1.

[Table 1]

Drawn Fibers	Spinning Method	Orifices of Spinneret	Fineness of Dawn Fiber (denier)	Intrinsic Viscosity of PET Polymer (dl/g)	Spinning Speed (m/min)	Spinning Tension (g/d)	Drawing Ratio	Monofilament Fineness (denier)
Example 1	3-ply	585	2000	1.3	3500	0.917	1.63	3.42
Example 2	3-ply	660	2000	1.3	3500	0.920	1.63	3.03
Example 3	3-ply	750	2000	1.4	3500	0.965	1.63	2.67
Example 4	3-ply	750	2000	1.3	3800	0.925	1.50	2.67
Example 5	4-ply	1000	2500	1.2	3800	0.938	1.50	2.50
Example 6	4-ply	1000	3000	1.2	3500	0.911	1.63	3.00
Comparative Example 1	1 ply	195	2000	1.1	2700	0.601	2.11	10.26
Comparative Example 2	1 ply	220	2000	1.0	3000	0.665	1.90	9.09
Comparative Example 3	2 ply	440	2000	1.2	3500	0.739	1.63	4.55
Comparative Example 4	2 ply	600	2000	1.3	3500	0.765	1.63	3.33
Comparative Example 5	2 ply	600	4000	1.0	3500	0.718	1.63	6.67

[Measurement of the properties of the drawn fibers]

[0060] To each drawn fiber prepared according to Examples 1 to 6 and Comparative Examples 1 to 5, the properties were measured by the following methods, and the measured properties are listed in the following Table 2.

1) Crystallinity: the density was measured by after preparing a density gradient tube by using CCl_4 and n-heptane, and the crystallinity was calculated by using the following calculation formula:

$$\text{PET Crystallinity (\%)} = \quad Xc\,(\%) = \left[\frac{\rho - \rho_a}{\rho_c - \rho_a} \right] \times 100$$

wherein, ρ_a = 1.336, and ρ_c = 1.457 in case of the PET.

2) Amorphous orientation factor (AOF): the AOF was calculated according to the following formula by using the birefringence index measured by using a polarized micrometer and the crystal orientation factor (COF) measured by an X-ray diffraction (XRD):

$$\text{AOF} = (\text{birefringence index} - \text{crystallinity (\%)} * 0.01 * \text{COF} * 0.275)/((1 - \text{crystallinity (\%)} * 0.01) * 0.22).$$

3) Tensile strength (g/d): the tensile strength of the fiber was measured by using a universal testing machine (UTM) according to ASTM D 885 method.

4) Intermediate elongation (%) and breaking elongation (%): the intermediate elongation (@ 4.5 g/d load) and the breaking elongation were measured by using a universal testing machine (UTM) according to ASTM D 885 method.

5) CV of cross sectional area (%): the CV value of cross sectional area was obtained by using Analysis Five program after measuring the cross sectional area of the fibers by photographing the cross section of the fibers with an optical microscope (Olympus BX51).

[Table 2]

Properties of Drawn Fibers	Crystallinity (%)	AOF	Tensile Strength (g/d)	Intermediate Elongation (%)	Breaking Elongation (%)	C.V. of Cross Sectional Area (%)
Example 1	46.2	0.185	8.7	4.9	15.1	7.20
Example 2	46.8	0.171	8.8	5.2	13.9	6.31
Example 3	48.1	0.160	9.2	5.0	13.7	5.19
Example 4	46.0	0.152	8.6	5.1	14.8	5.25
Example 5	45.5	0.128	8.3	5.0	15.6	4.76
Example 6	46.7	0.176	8.8	5.1	15.7	6.01
Comparative Example 1	45.2	0.313	8.5	6.6	10.7	15.87
Comparative Example 2	45.6	0.274	8.3	6.4	11.1	14.05
Comparative Example 3	45.0	0.231	8.3	5.8	14.4	9.25
Comparative Example 4	44.8	0.212	8.4	5.9	13.2	10.12
Comparative Example 5	41.7	0.255	7.5	6.2	13.9	11.09

[0061] As shown in Table 1 and Table 2, Comparative Examples 1 to 5 prepared the drawn fibers of 2000 denier or more by applying 1-ply or 2-ply co-spinning method. However, it is recognized that the drawn fibers did not satisfy the AOF of 0.01 to 0.2 and showed excessively large CV of cross sectional area even though the ultrahigh speed spinning technology was applied thereto. And, it is found that the fibers of Comparative Examples 1 to 5 showed inferior tensile strength on the whole.

[0062] Particularly, the fibers of Comparative Examples 1 to 3 showed the strength to some degree but they did not exhibit uniform properties because of very large CV of cross sectional area. And the fiber of Comparative Example 4 showed inferior strength and uneven properties because of large CV of cross sectional area.

[0063] In comparison, Examples 1 to 6 prepared the drawn fibers by 3-ply or 4-ply co-spinning method, and it is recognized that the drawn fibers satisfied the crystallinity of 40 to 50%, the AOF of 0.01 to 0.2, the monofilament fineness of 2.5 to 4.0 denier, the CV of cross sectional area of 8.0 % or less, and the total fineness of 2000 to 4000 denier at the same time. Particularly, it is recognized that the fibers were superior in the properties such as the tensile strength, the intermediate elongation, the breaking elongation, and the like while exhibiting uniform properties due to their low CV of cross sectional area.

[Preparation of tire cords]

<u>Examples 7 to 12</u>

[0064] The PET tire cords were respectively prepared by 'Z' twisting the drawn fiber prepared according to any one of Examples 1 to 6 with a specific total fineness and a twisting level per unit length (TPM); 'S' twisting 2 ply of the Z twisted fibers together with the same twisting level; dipping the same in an RFL adhesive solution; and drying and heat-treating the same. At this time, the drawn fibers used therein, the fineness of the drawn fibers, the twisting multiplier

(TM), and the heat-treating conditions for the cord were same as listed in Table 3, and the composition of RFL adhesive solution and the drying conditions followed conventional conditions for treating a PET cord.

Comparative Examples 6 to 10

[0065] The PET tire cords were prepared by using the drawn fibers prepared according to the conditions of Comparative Examples 1 to 5, and the drawn fibers used therein, the fineness of the drawn fibers, the twisting multiplier (TM), and the heat-treating condition for the cord were same as listed in Table 3.

[Table 3]

Cords	Drawn Fibers used	Fineness of Drawn Fiber (denier)	Twisting Number (TM)	Ply	Heat-treating Condition of Cord
Example 7	Example 1	2000	13.9	2	245~260 °C, 90 sec. or more
Example 8	Example 2	2000	13.9	2	245~260 °C, 90 sec. or more
Example 9	Example 3	2000	13.9	2	245~260 °C, 90 sec. or more
Example 10	Example 4	2000	13.9	2	245~260 °C, 90 sec. or more
Example 11	Example 5	2500	13.9	2	245~260 °C, 90 sec. or more
Example 12	Example 6	3000	13.9	2	245~260 °C, 90 sec. or more
Comparative Example 6	Comparative Example 1	2000	13.9	2	245~260 °C, 90 sec. or more
Comparative Example 7	Comparative Example 2	2000	13.9	2	245~260 °C, 90 sec. or more
Comparative Example 8	Comparative Example 3	2000	13.9	2	245~260 °C, 90 sec. or more
Comparative Example 9	Comparative Example 4	2000	13.9	2	245~260 °C, 90 sec. or more
Comparative Example 10	Comparative Example 5	4000	13.9	2	245~260 °C, 90 sec. or more

[Measurement of the properties of the tire cords]

[0066] To each tire cord prepared according to Examples 7 to 12 and Comparative Examples 6 to 10, the properties were measured by the following methods, and the measured properties are listed in the following Table 4.

1) Tensile strength (g/d): the tensile strength of the cord was measured by using a universal testing machine (UTM) according to ASTM D 885 method.

2) Intermediate elongation (%) and breaking elongation (%): the intermediate elongation (@ 4.5 g/d load) and the breaking elongation were measured by using a universal testing machine (UTM) according to ASTM D 885 method.

3) Dry heat shrinkage rate (%): the dry heat shrinkage rate was measured by using a dry heat shrinkage rate measuring device (MK-V produced by Testrite Co.) under the condition of providing the load of 0.01 g/d at 177 °C for 2 min.

4) Dimensional stability index (E-S index): the sum of the intermediate elongation and the dry heat shrinkage rate

measured by above methods.

[Table 4]

Properties of Cords	Tensile Strength (g/d)	Intermediate Elongation (%)	Breaking elongation (%)	Dry Heat Shrinkage Rate (%)	ES Index (%)
Example 7	7.83	4.0	17.2	2.6	6.6
Example 8	7.92	4.0	17.7	2.4	6.4
Example 9	8.28	4.0	15.4	2.2	6.2
Example 10	7.74	4.0	16.0	1.8	5.8
Example 11	7.47	4.0	16.8	1.3	5.3
Example 12	7.92	4.1	16.3	2.3	6.4
Comparative Example 6	7.65	4.1	13.9	5.1	9.2
Comparative Example 7	7.47	4.0	16.3	4.9	8.9
Comparative Example 8	7.47	4.1	13.1	3.5	7.6
Comparative Example 9	7.56	4.1	14.4	3.0	7.1
Comparative Example 10	6.75	4.1	15.7	4.1	8.2

[0067] As shown in Table 3 and Table 4, the cords of Comparative Examples 6 to 10 did not satisfy the preferable range of tensile strength, breaking elongation, or E-S index because of using the drawn fibers prepared by applying 1-ply or 2-ply co-spinning method. Particularly, the cords of Comparative Examples 6 to 8 showed poor dimensional stability because the E-S indices indicating the dimensional stability were increased as disclosed above. Furthermore, the cord of Comparative Example 9 was inferior in the dry heat shrinkage rate and the E-S index. And, in the case of Comparative Example 10, it is recognized that the cord exhibited poor properties such as low tensile strength and so on. It seems because the tire cords of Comparative Examples were prepared by using the drawn fibers of Comparative Examples which did not satisfy the proper range of AOF and CV of cross sectional area

[0068] In comparison, since the tire cords of Examples 7 to 12 were prepared by using the drawn fibers of Examples 1 to 6, the tensile strength, the breaking elongation, the intermediate elongation, the dry heat shrinkage rate, and the dimensional stability of the tire cords were in the preferable range, and it is recognized that the tire cords had excellent and uniform properties.

Claims

1. A drawn poly(ethyleneterephthalate) (PET) fiber, including 90 mol% or more of PET and having a crystallinity of 40 to 50%, an amorphous orientation factor (AOF) of 0.01 to 0.2, a monofilament fineness of 2.5 to 4.0 denier, a coefficient of variation (CV) of cross sectional area of 8.0 % or less, and a total fineness of 2000 to 4000 denier.

2. The drawn PET fiber according to claim 1, wherein the CV of cross sectional area is 2.5 to 7.5%.

3. The drawn PET fiber according to claim 1, having a tensile strength of 8.0 to 9.5 g/d.

4. The drawn PET fiber according to claim 1, having an intermediate elongation (@ 4.5 g/d load) of 4.0 to 6.5 % and a breaking elongation of 12.0 to 20.0 %.

5. A method of preparing a drawn PET fiber, including the steps of:

melt-spinning a polymer including 90 mol% or more of PET through a spinneret by 3-ply or 4-ply co-spinning method so as to prepare an undrawn PET fiber having a fineness of 2000 denier or more, wherein the spinning speed is 2500 to 4000 m/min; and
drawing the undrawn fiber with a drawing ratio of 1.4 to 2.0.

6. The method of preparing a drawn PET fiber according to claim 5, wherein the melt-spinning step is carried out with a spinning tension of 0.5 to 1.2 g/d.

7. The method of preparing a drawn PET fiber according to claim 5, wherein the undrawn fiber has a crystallinity of 10 to 30 %.

8. A method of preparing a PET tire cord, including the steps of:

preparing a drawn PET fiber according to the method of claim 5;
co-twisting the drawn fibers so as to prepare a twisted yarn; and
dipping the twisted yarn in an adhesive solution and heat-treating the same.

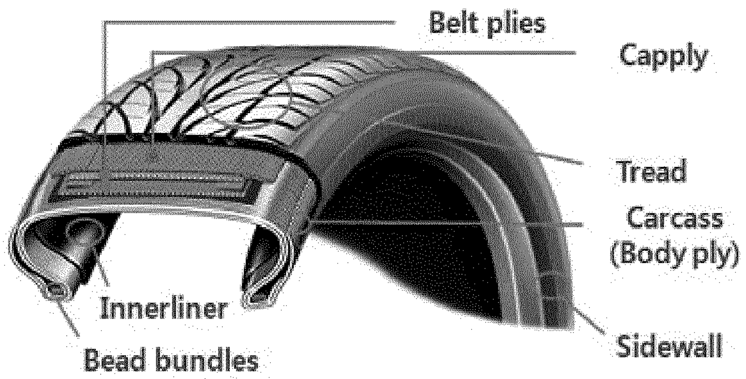
9. The method of preparing a PET tire cord according to claim 8, wherein the heat-treating step is carried out at the temperature of 230 to 260 °C for 90 to 360 sec.

10. A PET tire cord, having a total fineness of 4000 to 8000 denier, a tensile strength of 7.2 to 8.5 g/d, a dimensional stability index (E-S index) of 5.0 to 7.0 %, wherein the E-S index is the sum of a dry heat shrinkage rate after heat-treatment at 177 °C for 2 min under the load of 0.01 g/d and an intermediate elongation (@ 2.25 g/d load).

11. The PET tire cord according to claim 10, having an intermediate elongation (@ 2.25 g/d load) of 3.0 to 5.5 % and a breaking elongation of 15.0% or more.

12. The PET tire cord according to claim 10, which is used as a cord for body ply of a pneumatic tire.

Fig. 1


Belt plies
Capply
Tread
Carcass
(Body ply)
Sidewall
Innerliner
Bead bundles