(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 207 489**
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 86108904.3

(22) Date of filing: 01.07.86

(51) Int. Cl.[4]: D 01 F 6/62
D 01 D 5/098, D 02 G 1/18

(30) Priority: 02.07.85 JP 143990/85

(43) Date of publication of application:
07.01.87 Bulletin 87/2

(84) Designated Contracting States:
DE FR GB

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(54) Highly-shrinkable polyester fiber, process for preparation thereof, blended polyester yarn and process for preparation thereof.

(57) A highly-shrinkable polyester fiber composed of a polyester comprising ethylene terephthalate units as main recurring units and having a birefringence (Δn) of from 0.130 to 0.165, wherein the boiling water shrinkage is at least 30% and the peak temperature and peak value of the thermal stress are 90 to 105°C and at least 0.4 g/de, respectively. The fiber has excellent shrinkability as well as high heat resistance, dimensional stability and alkali resistance and provides a blended polyester yarn excellent in bulkiness and hand.

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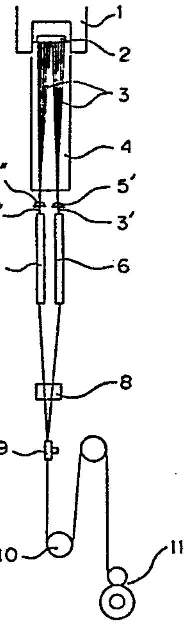
Fig. 4



HIGHLY-SHRINKABLE POLYESTER FIBER, PROCESS FOR PREPARATION THEREOF, BLENDED POLYESTER YARN AND PROCESS FOR PREPARATION THEREOF

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a highly-shrinkable polyester fiber and a process for the preparation thereof and to a blended polyester yarn and a process for the preparation thereof. More particularly, the present invention relates to a highly-shrinkable polyester fiber which has shrinkage characteristics comparable to those of a semi-drawn yarn (partially oriented yarn) though the strength and elongation characteristics are comparable to those of a drawn yarn and a process for the preparation thereof, as well as to a blended polyester yarn in which the highly-shrinkable fiber is contained as a highly-shrinkable component and a process for the preparation thereof.

2. Description of the Related Art

A blended polyester yarn capable of developing bulkiness through heat treatment can be obtained by blending polyester fibers differing in shrinkability (see, for example, U.S. Patent No. 3,200,576). Such a blended yarn becomes bulky through heat treatment by which the highly-shrinkable component polyester fiber (hereinafter may be referred to as highly-shrinkable fiber) shrinks, thereby bulging the lowly-shrinkable component polyester fiber (hereinafter may be referred to as lowly-shrinkable fiber). In this case, if a fiber having a large monofilament denier is employed as the highly-shrinkable fiber and a fiber having a small monofilament denier is employed as the lowly-shrinkable fiber, the bulky fiber obtained after heat treatment has a resilient hand and a soft feel to touch.

In order to obtain such a blended yarn of polyester fibers having different shrinkabilities, there have been employed many processes in which a plurality of fiber yarns having different shrinkabilities preliminarily imparted are blended. For example, U.S. Patent No. 4,153,660 proposes the following process: A spun fiber yarn obtained by melt spinning polyester into filaments from one spinneret and rapidly cooling the spun filaments are divided into two filament bundles, a spinning finish based on water is imparted to one of the filament bundles, and a finish having a boiling point higher than that of water is imparted to the other. Thereafter, the bundles are drawn while separately subjecting to heat treatment under the same condition and then are blended to form one blended yarn. However, the resulting fiber bundles can not have a satisfactory difference in shrinkability (boiling water shrinkage), since in the process, the difference in boiling water shrinkage is imparted between the two fiber bundles by utilizing the difference in boiling temperature of the employed spinning finishes. Therefore, the obtained blended yarn has only a small difference in shrinkability between the component fibers and, thus, the finally obtained bulked yarn is poor in bulkiness and can not have a satisfactory hand.

It may be thought to use a partially oriented yarn (hereinafter referred to as POY) obtained by melt spinning a polyester at a spin-take up speed of about 3,000 m/min as the highly-shrinkable fiber of the above-mentioned blended yarn, since the POY has a high boiling water shrinkage. However, the POY has various drawbacks, despite of its high boiling water shrinkage, due to the fact that it is inferior in heat resistance and dimensional stability to a polyester yarn which has been subjected to satisfactory heat setting after drawing (hereinafter may be referred to as drawn and heat set yarn). For example, as is described in Japanese Unexamined Patent Publication (Kokai) No. 55-98920, the use of blended yarns having a POY contained as the highly-shrinkable fiber is limited to extremely restricted specific fields. In addition, POYs have drawbacks in that they easily undergo plastic deformation by the stress applied thereto upon the handling thereof at the yarn-making and subsequent steps and further changes in physical properties such as boiling water shrinkage with the lapse of time so that a fabric finally obtained therefrom often has many fluffs, loops and/or unevenness and, thus, they are extremely hard to be handled. Furthermore, since POYs are poor in alkali resistance, when they are subjected to an alkali weight-reducing treatment which is generally employed to impart favorable hand and gloss to a polyester fabric, it is difficult to control the percentage reduction of weight upon the alkali weight-reducing treatment. The fiber in the thus obtained fabric may easily undergo fibrillation. Therefore, it is impossible to industrially subject a polyester fabric containing a POY to an alkali weight-reducing treatment.

As fibers having improved heat resistance, dimensional stability and alkali resistance over the POYs as well as a boiling water shrinkage higher than the drawn and heat set yarns, there may be mentioned a fiber obtained by drawing, without heat setting, an undrawn yarn prepared by melt spinning a polyester at a spin-take up speed of less than 3,000 m/min (non-heat set, drawn yarn), a fiber obtained by drawing a POY at room temperature (POY-cold drawn yarn), and a fiber obtained by drawing at room temperature a fully oriented yarn prepared by melt spinning a polyester at a high spin-take up speed of not less than 4,100 m/min (highly oriented, cold drawn yarn). These fibers have improved heat resistance, dimensional stability and alkali resistance as compared with POYs. However, they are poor in boiling water shrinkage and, thus, a fabric made of a blended yarn containing such fiber only has a poor bulkiness.

As means for obviating the disadvantages of the conventional highly-shrinkable polyester fiber, two of the present inventors already proposed, in the specification of Japanese Unexamined Patent Publication (Kokai) No. 60-259616, a polyester fiber which is obtained by extruding a molten polyester in an atmosphere maintained at a temperature higher than 200°C, cooling and soldifying the extrudate, again heating the formed filamentary yarn by travelling the yarn through an atmosphere maintained at 70 to 110°C, and then taking up the yarn at a speed of 4,500 to 6,000 m/min. The thus obtained fiber is amorphous despite of being highly oriented and, therefore, has a boiling water shrinkage substantially the same as that of a POY and improved heat resistance, dimensional stability and alkali resistance as compared with a POY. However, it has been proved that since this polyester fiber is intended to use as a semi-drawn yarn for the simultaneous drawing and false-twisting processing, if this fiber is directly subjected to the knitting or weaving process without a heat treatment, the deformation of the section of the single filament is still great and unevenness or kinking is readily caused in the obtained fabric.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a highly-shrinkable polyester which has shrinkage characteristics substantially the same as those of a POY and is also excellent in heat resistance, dimensional stability and alkali resistance and which can provide a fabric having no unevenness or kinking even if the fiber is directly subjected to a weaving or knitting operation, and a process for the preparation of this polyester fiber.

It is another object of the present invention to provide a blended polyester yarn which can provide a fabric having no defects such as streak based on the uneven shrinkage of the fiber and having fully satisfactory bulkiness and hand even after an alkali weight-reducing treatment, and a process for the preparation of the blended polyester yarn.

The inventors made research with a view to attaining the above-mentioned object, and found that in the process disclosed in the specification of Japanese Unexamined Patent Publication No. 60-259616, if the temperature for reheating the filamentary yarn is elevated, there can be obtained a highly-shrinkable polyester fiber having strength and elongation characteristics comparable to those of a drawn yarn and shrinkage characteristics comparable to those of a POY in combination and that a uniform fabric having excellent bulkiness can be obtained from a blended polyester yarn comprised of the highly-shrinkable polyester fiber and a drawn and heat set polyester yarn. The inventors have attained the present invention based on this finding.

Thus, the present invention provides a highly-shrinkable polyester fiber composed of a polyester comprising ethylene terephthalate units as main recurring units and having a birefringence (Δn) of from 0.130 to 0.165, wherein the boiling water shrinkage is at least 30% and the peak temperature and peak value of the thermal stress are 90 to 105°C and at least 0.4 g/de, respectively.

The present invention also provides a process for preparing a highly-shrinkable polyester fiber, which comprises extruding a melt of a polyester comprising ethylene terephthalate units as main recurring units from a spinneret into an atmosphere maintained at a temperature higher than 200°C, cooling and solidifying the extrudate by blowing cooling air to the extrudate, travelling the resulting filamentary yarn in an atmosphere heated at 120 to 160°C and extending along a length of 80 to 200 cm in the yarn travelling direction, and taking up the yarn at a speed of 4,000 to

6,000 m/min.

According to the present invention, there is further provided a blended polyester yarn comprising the above-mentioned highly-shrinkable polyester fiber in admixture with a lowly-shrinkable polyester fiber having a boiling water shrinkage lower than that of the highly-shrinkable polyester fiber.

Furthermore, according to the present invention, there is provided a process for the preparation of the blended polyester yarn, which comprises blending a highly-shrinkable polyster fiber having a boiling water shrinkage of at least 30% and obtained by the above-mentioned process with a lowly-shrinkable polyester fiber having a boiling water shrinkage lower than that of the highly-shrinkable polyester fiber.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph of the birefringence (Δn) and boiling water shrinkage (BWS) of a polyester fiber having a monofilament denier of about 2 deniers.

Fig. 2 is a graph showing the relationship between the birefringence (Δn) and SSC 10% strength (the stress at an elongation of 10% in a strength-elongation curve) of a polyester fiber.

Fig. 3 is a graph showing the relationship between the birefringence (Δn) and percentage reduction of weight upon an alkali weight-reducing treatment of a polyester fiber.

Fig. 4 is a schematic flow chart illustrating a process for the preparation of a blended polyester yarn of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The polyester usable for the present invention is a polyester comprising ethylene terephthalate units as main recurring units, and polyethylene terephthalate is mainly used. However, a copolyester formed by copolymerizing ethylene terephthalate with a comonomer in an amount not substantially changing the properties of the polymer, e.g., up to 15 mole%, may be used. Examples of the comonomer may include acids such as isophthalic acid, 2,6-naphthalenedicarboxylic acid, p-hydroxybenzoic acid, benzoic acid, diphenyl-4,4'-dicarboxylic acid, diphenoxyethane-dicarboxylic acid, 5-sodiumsulfoisophthalic acid, adipic acid, sebacic acid and cyclohexane-1,4-dicarboxylic acid, and diols such as cyclohexane-1,4-dimethanol, neopentyl glycol, bisphenol A, bisphenol S, polyalkylene glycols and tetramethylene glycol. The degree of polymerization in the polyester should be appropriately selected according to the kind of polyester and the intended use, and in case of polyethylene terephthalate, it is generally preferred that the intrinsic viscosity (η) be 0.40 to 0.95 as measured at 35°C as a solution in o-chlorophenol.

The highly-shrinkable polyester fiber of the present invention has a birefringence (Δn) and boiling water shrinkage (BWS) simultaneously satisfying the following formulae,

$0.130 < \Delta n \leqq 0.165$, preferably $0.133 \leqq \Delta n \leqq 0.165$

$30\% \leqq$ BWS, preferably $30\% \leqq$ BWS $\leqq 45\%$

The Δn and BWS simultaneously satisfying the above formulae are in the obliquely lined area as shown in Fig. 1. Fig. 1 is a graph showing the relationship between the Δn and BWS of a polyester fiber having a monofilament denier of about 2 deniers, in which the abscissa represents the Δn and the ordinate represents the BWS. In Fig. 1, curve F is a graph showing the relationship between the Δn and BWS of polyester fibers obtained by varying the spin-take up speed, in which point a shows the Δn and BWS of a POY-cold drawn polyester fiber obtained by drawing at room temperature (cold drawing) a fiber having a Δn of 0.05 and a BWS of 40% as shown at point a' on curve F and point b shows the Δn and BWS of a highly oriented, cold drawn polyester fiber obtained by drawing at room temperature (cold drawing) a fiber having a Δn of 0.09 and a BWS of 4% as shown at point b' on curve F. Point c shows the Δn and BWS of a non-heat set, drawn polyester fiber obtained by drawing at 70 to 80°C, without subjecting to heat setting, an undrawn yarn prepared by melt spinning a polyester at a spin-take up speed of 1,500 m/min. The area having oblique lines shows the scope of the Δn and BWS (except for the Δn of 0.130) of the highly-shrinkable polyester fiber according to the present invention as mentioned above. As is apparent from Fig. 1, the highly-shrinkable polyester fiber of the present invention has a high Δn and a high BWS in combination, in contrast to the conventional highly-shrinkable polyester fibers, i.e., the POY at point a', POY-cold drawn yarn at point a, highly oriented, cold drawn yarn at point b and non-heat set, drawn yarn at point c.

If the fiber has a Δn as low as not higher than 0.130, the fiber is fused to be bonded, rendered brittle and hardened at the subsequent heat treatment steps, and the strength is reduced and the elongation is increased. Accordingly, when the fiber is handled, fluffs and loops are formed even by a slight stress or the sections of single filaments are easily deformed, with the result that various nonuniformities such as dyeing unevenness, shape uneveness and streak unevenness are caused. If the fiber has a Δn higher than 0.165, the residual elongation of the fiber is reduced, and fluffing or breaking is caused in the preparation or weaving or knitting process and the process becomes unstable. If the fiber has a BWS as low as not higher than 30%, a fabric obtained by mix-weaving or mix-knitting such a low BWS fiber and a drawn and heat set yarn can not exhibit, after heat treatment, a satisfactory bulkiness and good hand and appearance.

In the highly-shrinkable polyester fiber of the present invention, in addition to the high Δn and high BWS, it is also indispensable that the peak temperature of the thermal stress (Tmax) should be 90 to 105°C and the peak value of the thermal stress (TSTmax) should be at least 0.4 g/de, preferably 0.4 to 0.6 g/de. If Tmax is lower than 90°C or TSTmax is less than 0.4 g/de, in a fabric obtained by mix-weaving or mix-knitting the highly-shrinkable polyester fiber with a drawn and heat set yarn, at the heat treatment to make the fabric bulky, manifestation of the bulkiness is uneven and the hand is insufficient, since the shrinkage stress of the highly-shrinkable fiber is insufficient. If Tmax exceeds 105°C, a fabric formed from the highly shrinkable fiber by mix-weaving or mix-knitting with a drawn and heat set yarn is defective in that at a heat treatment in boiling water at the scouring step where the relaxing heat treatment is generally conducted, no sufficient difference of the shrinkage be manifested so that the fabric becomes to have a paper-like hand.

The highly-shrinkable polyester fiber of the present invention can provide a bulky fabric or a fabric having a special appearance or hand by mix-weaving or mix-knitting with a drawn and heat set yarn to form a fabric, subjecting the fabric to a relaxing heat treatment and, if necessary, performing a raising treatment. Further, a bulky spun yarn can be obtained by cutting the highly-shrinkable fiber of the present invention, mix-spinning the resulting staple fiber with a lowly thermally shrinkable staple fiber and subjecting the resulting mixed fiber to a relaxing heat treatment.

The highly-shrinkable polyester fiber of the present invention has a high SSC 10% strength (the stress at an elongation of 10% in a strength-elongation curve) and, in addition, is excellent in alkali resistance, as is seen from Figs. 2 and 3. Figs. 2 and 3 are graphs respectively showing the relationships between the Δn and SSC 10% strength and the Δn and percentage reduction of weight upon an alkali weight-reducing treatment (alkali weight-reduction percentage) of a polyester fiber, in which the abscissa represents Δn and the ordinate represents the SSC 10% strength or the alkali weight-reduction percentage.

The alkali weight-reduction percentage as shown in Fig. 3 is a value determined by treating the polyester fiber in an solution of 35 g/l of sodium hydroxide in water at 100°C for 1 hour, and calculating according to the following formula,

$$\text{Alkali weight-reducing percentage (\%)} = \frac{m_1 - m_2}{m_1} \times 100$$

in which m_1 represents the weight (g) of the polyester fiber before the alkali treatment, and m_2 represents the weight (g) of the polyester fiber after the alkali treatment.

As is apparent from Fig. 2, the highly-shrinkable fiber of the present invention has an SSC 10% strength higher than 3 g/de because of its high Δn higher than 0.130. Therefore, the highly-shrinkable fiber does not easily undergo plastic deformation upon the handling thereof at the yarn-making and subsequent steps and can provide a uniform fabric.

Furthermore, the highly-shrinkable polyester fiber of the present invention is superior in the alkali resistance to conventional highly-shrinkable polyester fibers, such as a POY, as is seen from Fig. 3, and thus, is suitable for the use in a shrinkage-differing fiber blended yarn obtained by being blended with a lowly-shrinkable polyester fiber such as a drawn and heat set yarn. This is because an alkali weight-reducing treatment is generally effected for improving the hand and gloss of a polyester fabric, and a fabric composed of such a shrinkage-differing fiber blended yarn is often subjected to the alkali weight-reducing treatment for the same purpose.

However, since a conventional highly-shrinkable fiber such as a POY as used in the shrinkage-differing fiber blended yarn are extremely poorer in the alkali resistance than a lowly-shrinkable fiber such as a drawn and heat set yarn and it is difficult to control the percentage reduction of weight of the highly-shrinkable fiber contained in the blended yarn upon the alkali weight-reducing treatment, the shrinkage-differing fiber blended yarn obtained by using such a highly-shrinkable fiber can not exhibit a satisfactory hand and gloss after the alkali weight-reducing treatment. On the other hand, if a POY-cold drawn yarn (as shown at point a in Fig. 1), highly oriented, cold drawn yarn (as shown at point b in Fig. 1) or non-heat set, drawn yarn (as shown at point c in Fig. 1) having an improved alkali resistance is employed as the highly-shrinkable fiber component instead of the POY having a poor alkali resistance, the obtained shrinkage-differing fiber blended yarn can not exhibit a well satisfactory bulkiness because of the small difference of the shrinkage.

Contrary to this, a shrinkage-differing fiber blended polyester yarn obtained by blending the highly-shrinkable polyester fiber of the present invention having shrinkage characteristics comparable to a POY and an excellent alkali resistance in combination with a lowly-shrinkable polyester fiber having a boiling water shrinkage lower than that of the highly-shrinkable polyester fiber can exhibit a satisfactory bulkiness, hand and gloss even after the alkali weight-reducing treatment.

In the blended yarn, the lowly-shrinkable fiber preferably has a boiling water shrinkage not higher than 12%, more preferably 4% to 8%. If the boiling water shrinkage of the lowly-shrinkable fiber is higher than 12% the resulting blended yarn may have a hard hand after the relaxing heat treatment, while it may be difficult to prepare a lowly-shrinkable polyester fiber having a boiling water shrinkage of less than 4%.

Preferably, the difference in boiling water shrinkage between the highly-shrinkable fiber and lowly-shrinkable fiber constituting the blended yarn is at least 30% and the ratio of the monofilament denier (A) of the highly-shrinkable fiber to the monofilament denier (B) of the lowly-shrinkable fiber (monofilament denier ratio) is at least 1.5. If the difference in boiling water shrinkage is less than 30%, the bulkiness of the finally obtained fabric may be poor, and if the monofilament denier ratio is less than 1.5, the finally obtained fabric may have a hard hand.

In order to make the manifestation of even bulkiness possible in a fabric in which a blended yarn as mentioned above is employed, it is preferred that the blended yarn has entanglements, especially entanglements of a number of 5 to 70 per 1 meter. If the blended yarn has less than 5 entanglements/m the bulkiness of the resulting fabric may become uneven, while if the entanglements exceeds 70 per 1 meter fluffs and loops may easily be caused at the entanglement-imparting step and the resulting fabric may have a fretting appearance such as called as flash.

In order to obtain the above-mentioned highly-shrinkable polyester fiber of the present invention on an industrial scale, it is important that a molten polyester, preferably in the state heated at a temperature higher than 290°C, should be extruded in a heated atmosphere from a spinneret, the extrudate should be cooled and solidified and the resulting yarn should be taken at a high speed after it has been heated again. In this process, it is important that the temperature of the atmosphere into which the molten polyester is extruded should be maintained at a level higher than 200°C. If this atmosphere temperature is lower than 200°C, crystallization in the fiber is advanced during the spinning operation, and therefore, the boiling water shrinkage of the obtained polyester fiber is smaller than 30%. It is preferred that the zone of this heated atmosphere should extend along a length of at least

13 cm, especially at least 15 cm, from the surface of the spinneret.

The yarn which has passed through the zone of the heated atmosphere is cooled and solidified by blowing cooling air to the yarn, and the yarn is then heated again. At the cooling step, it is preferred that cooling air be blown to the yarn so that the yarn temperature is lower than Tg + 40°C, especially lower than Tg + 20°C, in which Tg represents the glass transition temperature of the polyester constituting the spun yarn. The Tg value of a polyester is measured by the method disclosed in the specification of U.S. Patent No. 2,556,295, and Tg of amorphous polyethylene terephthalate is about 70°C. If the temperature of the yarn to be re-heated is higher than Tg + 40°C, the subsequent heat treatment by re-heating is hardly uniformly accomplished, and therefore, the uniformity of the obtained polyester fiber is poor and unevenness or kinking is readily caused in a fabric as the final product. Cooling of the extruded yarn below Tg + 40°C is accomplished by blowing cooling air maintained at 20 to 10°C to the yarn, which has passed through the heated atmosphere just below the surface of the spinneret, along a length of 100 to 150 cm.

Re-heating is accomplished by passing the cooled yarn in an atmosphere heated at 120 to 160°C along a length of 80 to 200 cm in the travelling direction of the yarn. If the temperature of this atmosphere is lower than 120°C, the birefringence (orientation degree) of the obtained polyester is lower than 0.130, and therefore, the mechanical properties are insufficient for the yarn to be directly woven or knitted. If the temperature of the atmosphere is higher than 160°C, crystallization in the fiber is abruptly advanced during the re-heating operation and the boiling water shrinkage of the obtained polyester fiber is less than 30%. If the length of the zone of this re-heating treatment is shorter than 80 cm, the heated treatment for the yarn is insufficient, and therefore, the birefringence (Δn) of the obtained polyester fiber is lower than 0.130. If the length of the re-heating zone exceeds 200 cm, the space of the re-heating treatment zone is too large and the process is industrially disadvantageous.

In order to carry out this re-heating treatment on an industrial scale, it is preferred that a cooling zone having a length of 1 to 1.5 m be diposed below the zone of the atmosphere maintained at a temperature higher than 200°C and located just below the spinneret and a heating cylinder or a slit heater be arranged below the cooling zone to heat the atmosphere surrounding the running yarn to a predetermined temperature.

The temperature of the atmosphere as referred to herein is the temperature of the atmosphere measured at the point 10 mm apart from the running yarn.

In the present invention, if necessary, an oiling agent is applied to the re-heated yarn, and the yarn is taken up by goddet rolls and wound by a winder. The spin-take up speed is 4,000 to 6,000 m/min, preferably 4,500 to 6,000 m/min. If the take-up speed is lower than 4,000 m/min, the birefringence is lower than 0.130, and if the take-up speed is higher than 6,000 m/min, a special high-speed winder becomes necessary and the threadability at the start of spinning or the winding stability during spinning is degraded and no good results can be obtained.

In the present invention, if the spun yarn is bundled by a guide or the like before the re-heating treatment, tension unevenness is readily caused by a frictional resistance given to the yarn by the guide and the evenness of the obtained polyester fiber is degraded. However, when bad influences of the frictional resistance are eliminated by using an oiling agent-supplying guide or a guide where an appropriate oiling agent is leaked out from the interior, the yarn may be bundled.

As means for imparting a good coherency to the yarn, a method in which a turbulent flow or swirling flow of a gas is caused to act on the yarn before winding or after application of the oiling agent to attain an interlacing or intertwisting effect is preferable to the above-mentioned method using a guide.

By blending the thus obtained highly-shrinkable polyester fiber having a boiling water shrinkage of not less than 30% and preferably of not higher than 45% with a lowly-shrinkable polyester fiber having a boiling water shrinkage lower than that of the highly-shrinkable polyester fiber, preferably of not higher than 12%, there can be obtained a blended yarn exhibiting a satisfactory bulkiness and good hand and gloss even after the alkali weight-reducing treatment.

As the lowly-shrinkable fiber usable for the blended yarn, there may be mentioned fibers obtained by hitherto known methods, for example, the separate drawing method in which an undrawn yarn once taken up and wound after melt spinning is drawn and heat set, the direct spin-draw method in which an undrawn yarn taken up onto a heating take-up roller is continuously drawn, without being wound, between the take-up roller and a heating draw roller, and the running zone-heating spinning method as disclosed, for example, in the specification of U.S. Patent No. 4,388,275, in which a yarn once cooled and solidified after melt spinning is heated to 185 to 250°C along a length of 80 to 200 cm in the yarn-running direction. Of these methods, the direct spin-draw method and the running zone-heating spinning method are preferred in view of their excellent productivity.

In the process for blending the highly-shrinkable fiber with the lowly-shrinkable fiber, it is preferred that entanglements of a number of 5 to 70 per 1 meter be imparted to the yarn by a compressed air entangling treatment using an compressed air entangling apparatus such as an interlacing nozzle known from British Patent No. 924,089.

The blended yarn can be prepared efficiently according to the process as shown in Fig. 4. Fig. 4 is a schematic flow chart illustrating a process for the preparation of the blended yarn of the present invention.

Referring now to Fig. 4, a filamentary yarn 3 extruded from a spin block 1 through a spinneret 2 into an atmosphere maintained at a temperature of not lower than 200°C and cooled and solidified in a cooling air cylinder 4 is divided into two yarn bundles 3', 3" by bundling guides 5', 5". One yarn bundle 3' passed through a heating cylinder 6 the atmosphere in which is heated to a temperature of 120 to 160°C, and the other yarn bundle 3" passes through a heating cylinder 7 the atmosphere in which is heated to a temperature of 185 to 250°C. The yarn bundles 3', 3" heat treated in the heating cylinders 6, 7 are applied with an oiling agent by an oiling device 8, combined and subjected to a compressed air entangling treatment by an interlacing nozzle 9, taken up on a take-up roller 10 at a take-up speed of 4,000 to 6,000 m/min, and then wound by a winder 11.

The division of the yarn 3 may be effected by passing a filamentary yarn extruded from one spinneret through a plurality of bundling guides as shown in Fig. 4 or by extruding a plurality of filamentary yarns from a spinneret having plurally divided groups of spinning holes or from plurally divided spinnerets. One or both of the heating cylinders 6, 7 may be replaced by a slit heater or the like, and the heating cylinders may have different lengths.

The reasons why a blended yarn differing in boiling water shrinkage can be obtained by the process as shown in Fig. 4 may be presumed as follows.

At the heating cylinders 6, 7, when the yarns once cooled and solidified are re-heated in the heating cylinders and reach a temperature close to the temperature at which the molecular mobility of the polymer constituting the filamentary yarn appears (glass transition temperature Tg). The molecular orientation is effected under the action of a drawing stress corresponding to the stress due to the friction of the yarn and air produced between the spinneret and the heating cylinder, and simultaneously, crystallization in the fiber is advanced. However, since in the yarn 3' which passes through the heating cylinder 6 having an atmosphere temperature maintained at 120 to 160°C and is taken up at a take-up speed of 4,000 to 6,000 m/min, crystallization is not abruptly advanced while the molecular orientation is advanced in the heating cylinder 6 due to the drawing action, the yarn 3' becomes an amorphous, highly-shrinkable fiber having a high boiling water shrinkage and large shrinking force. On the other hand, since in the yarn 3" which passes through the heating cylinder 7 having an atmosphere temperature of 185 to 250°C higher than that of the heating cylinder 6, the molecular orientation due to the drawing action and abrupt crystallization in the fiber are advanced in the heating cylinder 7, the yarn 3" becomes a crystalline, lowly-shrinkable fiber having a low boiling water shrinkage and small shrinking force.

Thus, by blending and entangling the highly-shrinkable fiber and the lowly-shrinkable fiber at the interlacing nozzle 9, a blended yarn largely differing in boiling water shrinkage and having a high handleability can be obtained.

According to the preparation process of the highly-shrinkable polyester fiber of the present invention, a molten polyester is extruded in a heated atmosphere, the extrudate is cooled and re-heated and the yarn is taken up at a high speed, and the re-heating temperature is maintained at a level higher than the temperature disclosed in the specification of Japanese Unexamined

Patent Publication No. 60-259616. By the drawing action at the re-heating treatment, the birefringence (orientation degree) of the obtained fiber is further improved. Moreover, the upper limit of the re-heating temperature is not so high as causing abrupt crystallization, and therefore, the obtained fiber is still amorphous and retains a high shrinkability and a large shrinking force.

Since the so-obtained highly-shrinkable polyester fiber has a high orientation degree even though it is amorphous, even when the fiber is directly knitted or woven, the deformation of the cross-section of the single filament is small and generation of unevenness or kinking, which is due to the deformation of the cross-section of the single filament, can be prevented.

Furthermore, since the blended yarn obtained by blending the above-mentioned highly-shrinkable polyester fiber with a polyester fiber of a low boiling water shrinkage such as a drawn and heat set yarn has a satisfactorily large difference between the constitutional fibers and the highly-shrinkable fiber has an alkali resistance comparable to the drawn and heat set yarn, the percentage reduction of weight is easily controlled at the alkali weight-reducing treatment and the blended obtained after the alkali weight-reducing treatment can exhibit an excellent bulkiness and the good hand and gloss.

The highly-shrinkable polyester fiber of the present invention can be fed directly to the weaving or knitting process and, particularly, is suitable for the highly-shrinkable fiber of a shrinkage-differing fiber blended yarn, since the fiber is excellent in heat resistance, dimensional stability and alkali resistance. Moreover, the highly-shrinkable polyester fiber of the present invention can be handled very easily during various processing steps.

The characteristics as mentioned herein are determined according to the following methods.

1. Birefringence (Δn)

The birefringence is measured by using a polarizing microscope according to the Senarmont method.

2. Boiling Water Shrinkage

The sample is heat treated in boiling water at 100°C for 30 minutes in the unrestricted state, and the boiling water shrinkage is expressed as the ratio (%) of the length shrunk by the treatment to the original length of the sample.

3. Thermal Stress

The thermal stress is measured under conditions of an initial tension stress of 1 denier/39 g, a sample length of 10 cm and a heating rate of 2.5°C/sec by using a thermal stress tester (Model KE-II supplied by Kanebo Engineering Co.).

4. Number of Entanglements

The sample of a length of 1.2 m is vertically suspended by tying one end thereof to a fixed nail and applying a load of 0.2 g/de (load of 0.2 g x total denier) to the other end. A hook having a weight of 1.0 g/de (hook weight of 1.0 g x total denier) is inserted into the center of the sample filamentary yarn vertically suspended and allowed to fall down by its own weight. When the hook has stopped owing to the entanglement, the hook is again inserted into the yarn at a point of 1 mm below the point at which the hook stopped and a allowed to fall down. This procedure is repeated and the number of stops is determined over the length of 1 m. The number of stops is the number of entanglements.

The present invention will now be further described with reference to the following illustrative but not limitative examples.

Example 1

A chip of polyethylene terephthalate having an intrinsic viscosity of 0.64 (having a melting point of 261°C and a glass transition temperature of 68°C) was molten and extruded in an atmosphere having a length of 15 cm and maintained at a temperature shown in Table 1 (the temperature of the atmosphere just below the spinneret) for a spinneret having 36 holes, each having a diameter of 0.27 mm, and in a zone of 1 m below this atmosphere, the extrudate was cooled and solidified by blowing cooling air traversely to the extrudate. Then, the resulting yarn was travelled through a heated atmosphere having a length of 100 cm to re-heat the yarn. Then, an oiling agent was applied to the yarn by an oiling roller and the yarn was taken up by a pair of goddet rollers to obtain a 75-denier yarn.

The extrusion temperature of the molten polyester (spun polymer temperature), the temperature of the cooling air, the yarn temperature after re-heating and the take-up speed are shown in Table I. Moreover, the physical properties of the obtained fiber (yarn), such as the birefringence (Δn), the boiling water shrinkage, the thermal stress peak temperature (Tmax), the thermal stress peak value (TSTmax), the strength and the elongation, and the results of evaluation of the hand and kinking of the woven fabric obtained by using the obtained yarn are shown in Table I.

Table I

Run No.	Yarn-Preparing Conditions: Take-up Speed (m/min)	Spun Polymer Temperature (°C)	Temperature (°C) of Atmosphere below Spinneret	Cooling Air Temperature (°C)	Re-Heating Temperature (°C)	Yarn Temperature (°C) after Re-Heating	Properties of Yarn: Birefringence (Δn)	Boiling Water Shrinkage Factor	Thermal Stress: Tmax (°C)	Thermal Stress: TSTmax (g/de)	Strength (g/de)	Elongation (%)	Evaluation of Woven Fabric: Hand	Kinking
1	5000	295	250	15	60	52	0.082	9	70	0.22	3.5	53	x	xx
2	5000	295	250	15	80	63	0.108	60	82	0.25	3.8	45	x	x
3	5000	295	250	15	100	85	0.125	58	88	0.30	4.2	44	x	x
4	5000	295	250	15	110	91	0.130	51	94	0.33	4.5	41	Δ	Δ
5	5000	295	250	15	120	94	0.133	45	96	0.40	4.7	38	o	o
6	5000	295	250	15	150	98	0.138	40	100	0.40	4.8	37	o	o
7	5000	295	250	15	160	102	0.139	35	105	0.40	4.9	36	o	o
8	5000	295	250	15	170	107	0.140	20	120	0.41	4.9	36	x	o
9	5000	295	250	15	200	149	0.145	7	150	0.41	4.9	36	x	o
10	5000	295	250	15	300	168	0.147	6	171	0.42	4.9	36	x	o
11	5000	295	180	15	110	90	0.124	28	96	0.31	4.2	45	x	x
12	5000	295	180	30	110	90	0.122	25	98	0.30	4.3	43	x	x
13	5000	285	250	15	110	90	0.120	23	100	0.30	4.1	45	x	x
14	4000	295	250	15	110	94	0.078	12	94	0.20	3.5	75	x	xx
15	6000	295	250	15	110	87	0.135	6	95	0.38	4.6	38	x	o
16	5000	295	250	15	Room temperature	-	0.095	6	89	0.24	3.8	60	x	xx

Note

Samples of Run Nos. 5 through 7 are samples according to the present invention, while samples of Run Nos. 1 through 4 and 8 through 16 are comparative samples.

As is apparent from Table I, the woven fabrics composed of a highly-shrinkable polyester fiber within the scope defined in the present invention have no kinking or other defects and have a good hand.

Example 2

Polyester fibers were prepared in the same manner as described in Example 1 except that the spun polyester temperature, the temperature and length of the atmosphere below the spinnret, the temperature of cooling air, the length of the cooling air-blowing zone (cooling length), the re-heating temperature, the length of the re-heating zone and the take-up speed were changed as shown in Table II. The physical properties of the obtained fibers (yarns) and the results of evaluation of woven fabrics are shown in Table II.

Table II

Run No.	Yarn-Preparing Conditions									Properties of Yarn						Evaluation of Woven Fabric	
	Spinning Polymer Temperature (°C)	Atmosphere below Spinneret		Cooling Zone		Re-Heating Zone		Take-up Speed (m/min)	Birefringence (Δ n)	Boiling Water Shrinkage Factor (%)	Thermal Stress		Strength (g/de)	Elongation (%)	Hand	Kinking
		Temperature (°C)	Length (cm)	Cooling Air Temperature (°C)	Length (cm)	Temperature (°C)	Length (cm)				Tmax (°C)	TSTmax (g/de)				
17	295	285	15	15	100	165	100	5000	0.140	30	105	0.42	4.9	36	o	o
18	295	285	15	15	100	120	100	5000	0.133	45	96	0.40	4.7	38	o	o
19	295	285	15	15	100	105	100	5500	0.150	31	90	0.43	4.7	32	o	o
20	295	320	15	15	100	160	100	6000	0.165	35	105	0.45	4.7	28	o	o
21	295	200	15	15	100	120	100	5000	0.132	42	96	0.40	4.6	38	o	o
22	295	250	15	15	100	220	80	5000	0.133	43	96	0.40	4.6	37	o	o
23	295	250	15	15	100	120	200	5000	0.135	40	97	0.40	4.6	38	o	o

Note

Samples obtained at Run NOs. 17 through 23 are samples according the present invention.

Example 3

Each of the polyester fibers shown in Table I of Example 1 was combined with a polyethylene terephthalate multi-filament yarn (30 de/24 fil, birefringence of 0.159, boiling water shrinkage of 8.6%) and the combined yarn was passed through an interlacing apparatus. The obtained interlaced yarns were subjected to a shrinking heat treatment in boiling water at 100°C. Uniform and high bulkiness could be attained when the polyester fibers of Run Nos. 5 through 7 were used. In case of the polyester fibers of Run Nos. 8 through 10 where the heat treatment temperature was elevated, crystallization was advanced and the boiling water shrinkage was less than 30%, and therefore, interlaced yarns prepared by using these polyester fibers were insufficient in the bulkiness.

The polyester fibers having a birefringence lower than 0.130, which were obtained at Run Nos. 1 through 4, were readily deformed at the weaving step and hence, uneven shrinkage was readily caused and streaking unevenness was readily caused in the obtained fabric. When the polyesters having low birefringence and low boiling water shrinkage, which were obtained at Run Nos. 11 through 13, were used, fluffs and loops were readily formed at the combining and interlacing step and the fibers were readily deformed, and therefore, uniform bulkiness could not be obtained and hardening is caused by the shrinking heat treatment to degrade the hand.

In case of the interlaced yarn prepared by suing the polyester fiber of Run No. 15 where the spinning speed was increased, the boiling water shrinkage was lower than that of the drawn and heat set yarn, and therefore, the bulkiness was lost and the hand was degraded. The polyester fiber having a low birefringence, which was obtained at Run No. 14 where the spinning speed was low, was readily deformed, and the boiling water shrinkage was low and the hand was hard. The polyester fiber of Run No. 16 where the re-heating treatment was not carried out had a low boiling water shrinkage.

As is apparent from the foregoing, the highly-shrinkable polyester fiber within the scope of the present invention has a very high boiling water shrinkage, and if this fiber is combined with a lowly-shrinkable polyester fiber, a bulky blended yarn having a good appearance and hand can be obtained. The strength an elongation characteristics of the yarn are excellent, and when the yarn is handled, the yarn is not deformed or formation of fluffs and loops is prevented.

Incidentally, the bulkiness and hand were determined by organoleptic examination by skilled workers.

Example 4

According to the process as shown in Fig. 4, a chip of polyethylene terephthalate having an intrinsic viscosity of 0.64 (having a melting point 261°C and a glass transition temperature of 68°C) was molten and was extruded at a polymer temperature of 295°C in an atmosphere having a length of 15 cm and maintained at a temperature shown in Table III (the temperature of the atmosphere just below the spinneret) from a spinneret having 72 holes, each having a diameter of 0.27 mm, and in a zone of 1 m below this atmosphere, the extrudate was cooled and solidified by blowing cooling air transversely to the extrudate. Then, the yarn is divided into two filamentary yarns each having 36 filaments and the respective yarns were passed through heating cylinders having a length shown in Table III, applied with an oiling agent on an oiling roller, and subjected to a compressed air interlacing treatment on an interlacing nozzle. The interlaced and combined yarn was then taken up by a pair of goddet rollers and wound to obtain a

150-denier yarn.

The physical properties of the yarns at the exit of the heating cylinders and the physical properties of the woven fabrics obtained from the resulting blended yarns are shown in Table III.

Table III

Run No.	Yarn-Preparing Conditions: Temperature (°C) of Atmosphere below Spinneret	Yarn-Preparing Conditions: Cooling Air Temperature (°C)	Yarn-Preparing Conditions: Take-up Speed (m/min)	Highly-Shrinkable Fiber: Re-Heating Conditions: Atmosphere Temperature (°C)	Highly-Shrinkable Fiber: Re-Heating Conditions: Length (m)	Highly-Shrinkable Fiber: Properties of Yarn: Birefringence (Δn)	Highly-Shrinkable Fiber: Properties of Yarn: Boiling Water Shrinkage Factor (%)	Highly-Shrinkable Fiber: Properties of Yarn: Thermal Stress Tmax	Highly-Shrinkable Fiber: Properties of Yarn: Thermal Stress TSTmax	Highly-Shrinkable Fiber: Properties of Yarn: Strength (g/de)	Highly-Shrinkable Fiber: Properties of Yarn: Elongation (%)	Lowly-Shrinkable Fiber: Re-Heating Conditions: Atmosphere Temperature (°C)	Lowly-Shrinkable Fiber: Re-Heating Conditions: Length (m)	Lowly-Shrinkable Fiber: Properties of Yarn: Birefringence (Δn)	Lowly-Shrinkable Fiber: Properties of Yarn: Boiling Water Shrinkage Factor (%)	Lowly-Shrinkable Fiber: Properties of Yarn: Strength (g/de)	Lowly-Shrinkable Fiber: Properties of Yarn: Elongation (%)	Evaluation of Woven Fabric: Hand and Bulkiness	Evaluation of Woven Fabric: Kinking
*24	250	15	3000	140	1	0.048	60	96	0.20	2.4	130	200	1	0.072	7	3.2	67	x	x
*25	250	15	3500	140	1	0.057	55	96	0.26	2.6	75	200	1	0.095	7	3.7	48	x	x
26	250	15	4000	140	1	0.131	48	98	0.33	4.6	39	200	1	0.135	7	4.5	38	Δ ~ o	Δ ~ o
27	250	15	5000	150	1	0.138	40	100	0.40	4.8	37	200	1	0.145	7	4.9	36	o	o
28	320	15	6000	160	1	0.165	35	105	0.45	4.7	28	200	1	0.164	5	4.6	27	o	o
29	200	15	5000	150	1	0.133	42	100	0.40	4.6	38	200	1	0.145	7	4.9	36	o	o
*30	180	15	5000	150	1	0.134	28	100	0.40	4.6	35	200	1	0.138	7	4.7	34	o	x
*31	180	30	5000	150	1	0.134	29	100	0.40	4.6	36	200	1	0.138	7	4.7	35	o	x
*32	200	15	5000	100	1	0.125	58	88	0.25	4.2	44	200	1	0.145	7	4.8	36	Δ	x
*33	200	15	5000	110	1	0.130	51	94	0.33	4.5	41	200	1	0.145	7	4.9	35	Δ	Δ
*34	200	15	5000	170	1	0.140	20	120	0.41	4.9	36	200	1	0.145	7	4.9	34	x	o
35	200	15	5000	160	0.8	0.133	43	105	0.40	4.6	37	200	1	0.145	7	4.7	36	o	o
36	200	15	5000	120	2	0.135	40	98	0.41	4.6	38	200	1	0.144	6	4.9	36	o	o
37	200	15	5000	150	1	0.138	40	100	0.40	4.8	37	170	1	0.140	20	4.9	35	Δ ~ o	Δ ~ o
38	200	15	5000	150	1	0.137	39	100	0.40	4.7	38	180	1	0.142	14	4.9	35	Δ ~ o	Δ ~ o

Note

The samples of Run Nos. 24, 25 and 30 through 34 are comparative samples.

As is apparent from Table III, the fabric composed of the blended yarn within the scope as defined in the present invention is even and exhibits a good bulkiness and hand.

Comparative Example 1

The same polyester as used in Example 4 was spun at a spin-take up speed of 1,200 m/min. The spun yarn was drawn at a draw speed of 1,300 m/min and heat set at 200°C to obtain a draw yarn of 75 de/36 fil. The drawn yarn was a lowly-shrinkable fiber having a birefringence (Δn) of 0.164, a boiling water shrinkage of 8%, a strength of 5 g/de and an elongation of 28%.

Another drawn yarn obtained by repeating the above-mentioned procedure except that the heat setting at 200°C was not effected at the drawing step was a highly-shrinkable fiber having a birefringence (Δn) of 0.148, a boiling water shrinkage of 15%, a strength of 4.7 g/de and an elongation of 32%. These fibers were then subjected to a compressed air interlacing treatment on an interlacing nozzle to obtain a blended yarn and the bulkiness and kinking of the woven fabric prepared from the blended yarn were evaluated as described in Example 4.

The obtained woven fabric was even having no kinking or other defects, but has a poor bulkiness and hard hand.

Example 5

A woven fabric composed of the blended yarn as obtained at Run No. 27 in Table III of Example 4 was treated in an aqueous sodium hydroxide solution of a concentration of 35 g/l at 100°C for 1 hour. The weight loss of the treated fabric was 10% by weight. The obtained fabric was even and had a good bulkiness and hand.

For comparison, a woven fabric obtained by using a blended yarn composed of the drawn and heat set yarn as used in Comparative Example 1 (having a birefringence of 0.164, a boiling water shrinkage of 8%, a strength of 5 g/de and an elongation of 28%) a POY obtained by taking up at a spin-take up speed of 3,300 m/min (having a birefringence of 0.045, a boiling water shrinkage of 52% a strength of 2.4 g/de and an elongation of 125%) was subjected to an alkali treatment in the same manner as mentioned above. The obtained fabric had a hard hand and the surface of the fabric was readily whitened by friction. This phenomenon is due to the fact the POY was preferentially reduced in weight by the alkali treatment and became readily fibrillated.

CLAIMS

1. A highly-shrinkable polyester fiber composed of a polyester comprising ethylene terephthalate units as main recurring untis and having a birefringence (Δn) of from 0.130 to 0.165, wherein the boiling water shrinkage is at least 30% and the peak temperature and peak value of the thermal stress are 90 to 105°C and at least 0.4 g/de, respectively.

2. A highly-shrinkable polyester fiber as set forth in claim 1, wherein the birefringence (Δn) is not less than 0.133.

3. A highly-shrinkable polyester fiber as set forth in claim 1, wherein the boiling water shrinkage is not higher than 45%.

4. A process for the preparation of a highly-shrinkable polyester fiber, comprising extruding a melt of a polyester having ethylene terephthalate units as main recurring units from a spinneret into an atmosphere maintained at a temperature not lower than 200°C, cooling and solidifying the extrudate by blowing cooling air to the extrudate, travelling the resulting filamentary yarn in an atmosphere heated at 120 to 160°C and extending along a length of 80 to 200 cm in the yarn travelling direction, and taking up the yarn at a speed of 4,000 to 6,000 m/min.

5. A process as set forth in claim 4, wherein the temperature for the extrusion of the polyester melt is not lower than 290°C.

6. A process as set forth in claim 4, wherein the zone of the polyester melt-extruding atmosphere maintained at a temperature not lower than 200°C extends along a length of at least 13 cm from the surface of the spinneret in the yarn travelling direction.

7. A process as set forth in claim 4, wherein the cooling solidification of the extruded yarn is effected by blowing cooling air maintained below 20°c along a length of 100 to 150 cm to the yarn which has passed

through the atmosphere maintained at a temperature not lower than 200°C.

8. A blended polyester yarn comprising a highly-shrinkable polyester fiber as defined in claim 1 in admixture with a lowly-shrinkable polyester fiber having a boiling water shrinkage lower than that of said highly-shrinkable polyester fiber.

9. A blended polyester yarn as set forth in claim 8, wherein the birefringence of the highly-shrinkable polyester fiber is not less than 0.133.

10. A blended polyester yarn as set forth in claim 8, wherein the boiling water shrinkage of the highly-shrinkable polyester fiber is not higher than 45%.

11. A blended polyester yarn as set forth in claim 8, wherein the boiling water shrinkage of the lowly-shrinkable polyester fiber is not higher than 12%.

12. A blended polyester yarn as set forth in claim 8, wherein the difference in boiling water shrinkage between the highly-shrinkable polyester fiber and the lowly-shrinkable polyester fiber is not less than 30%.

13. A blended polyester yarn as set forth in claim 8, wherein the ratio (A/B) of the monofilament denier (A) of the highly-shrinkable polyester fiber to the monofilament denier (B) of the lowly-shrinkable polyester fiber is not less than 1.5.

14. A blended polyester yarn as set forth in claim 8, wherein the blended yarn has entanglements.

15. A blended polyester yarn as set forth in claim 8, wherein the number of the entanglements is 5 to 70 per 1 meter.

16. A process for the preparation of a blended polyester yarn, comprising blending a highly-shrinkable polyester fiber having a boiling water shrinkage of at least 30% and obtained by a process as defined in claim 4 with a lowly-shrinkable polyester fiber having a

boiling water shrinkage lower than that of said highly-shrinkable polyester fiber.

17. A process as set forth in claim 16, wherein the temperature for the extrusion of the polyester melt is not lower than 290°C.

18. A process as set forth in claim 16, wherein the zone of the polyester melt-extruding atmosphere maintained at a temperature not lower than 200°C extends along a length of at least 13 cm from the surface of the spinneret in the yarn travelling direction.

19. A process as set forth in claim 16, wherein the cooling solidification of the extruded yarn is effected by blowing cooling air maintained below 20°C along a length of 100 to 150 cm to the yarn which has passed through the atmosphere maintained at a temperature not lower than 200°C.

20. A process as set forth in claim 16, wherein the boiling water shrinkage of the highly-shrinkable polyester fiber is not higher than 45%.

21. A process as set forth in claim 16, wherein the boiling water shrinkage of the lowly-shrinkable polyester fiber in not higher than 12%.

22. A process as set forth in claim 16, wherein the difference in boiling water shrinkage between the highly-shrinkable polyester fiber and the lowly-shrinkable polyester fiber is not less than 30%.

23. A process as set forth in claim 16, wherein the highly-shrinkable fiber and the lowly-shrinkable fiber are blended by a compressed air entangling treatment.

24. A process as set forth in claim 16, wherein the number of the entanglements applied to the yarn is 5 to 70 per 1 meter.

Fig. 1

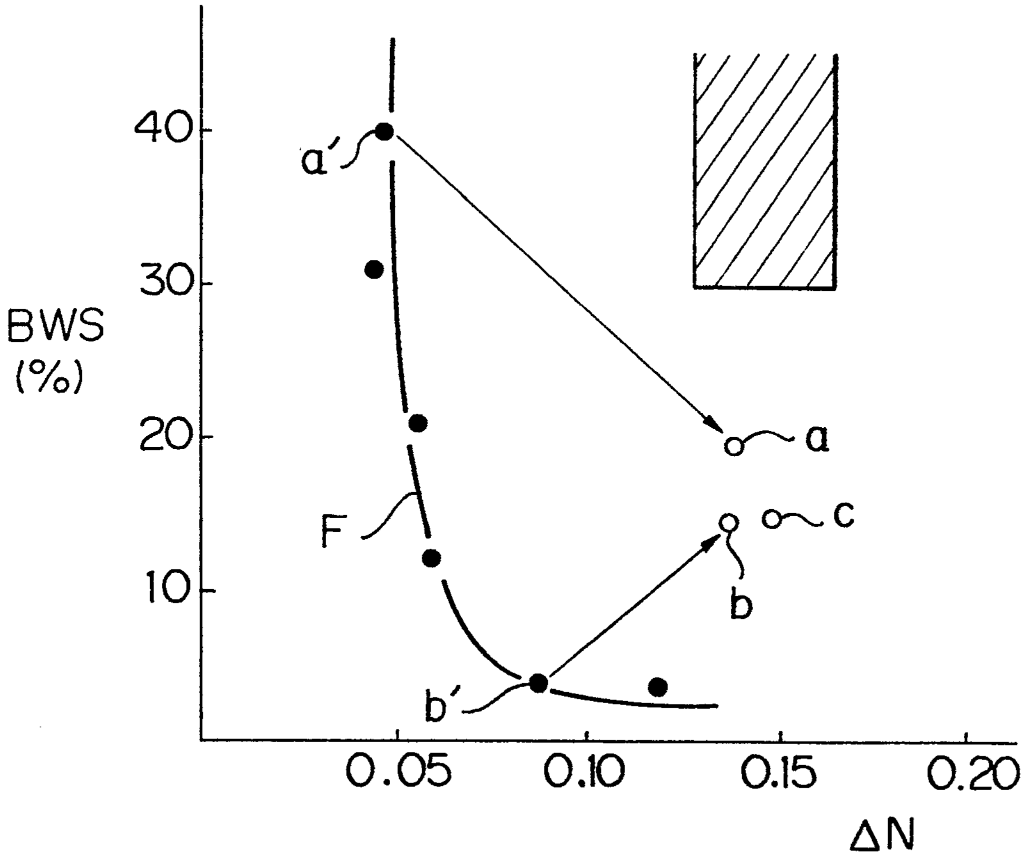


Fig. 2

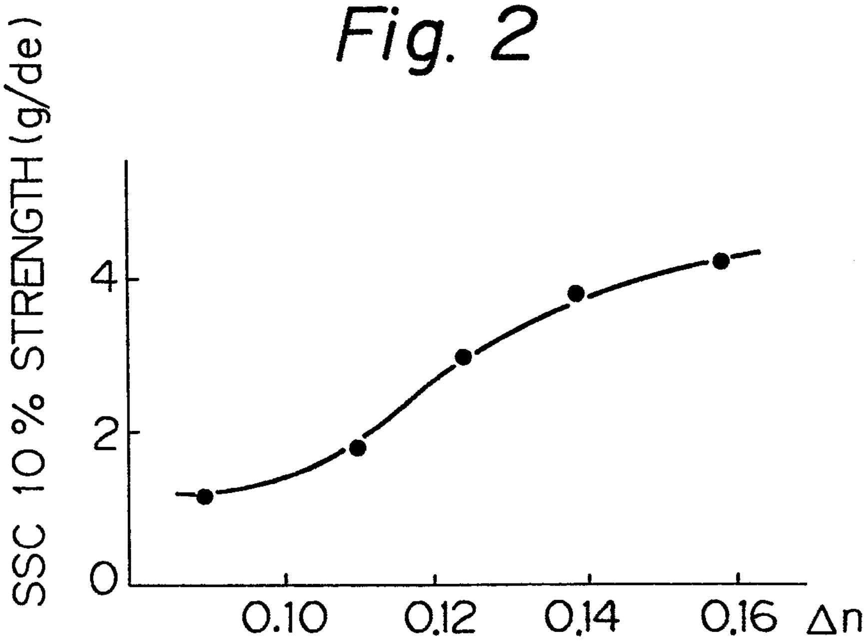

SSC 10 % STRENGTH (g/de)
4
2
0
0.10
0.12
0.14
0.16
Δn

Fig. 3

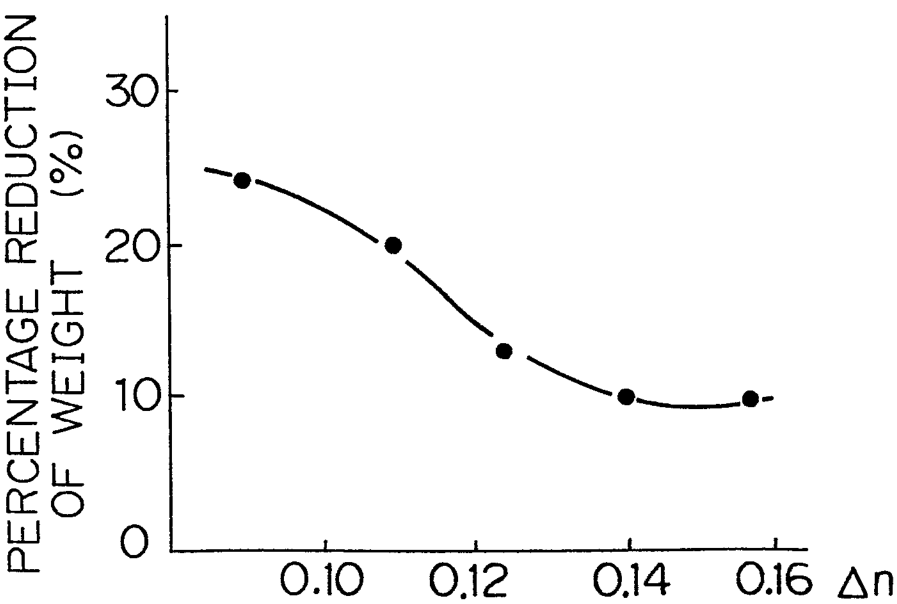

PERCENTAGE REDUCTION OF WEIGHT (%)
30
20
10
0
0.10
0.12
0.14
0.16
Δn

Fig. 4