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[54] COMPOSITE FILAMENTS HAVING AN ELASTIC CRIMPING PROPERTY

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[58] Field of Search 161/173, 175, 177; 264/168, 264/171, DIG. 26

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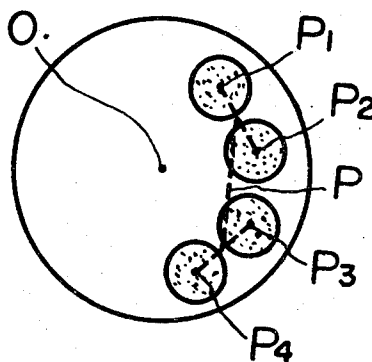
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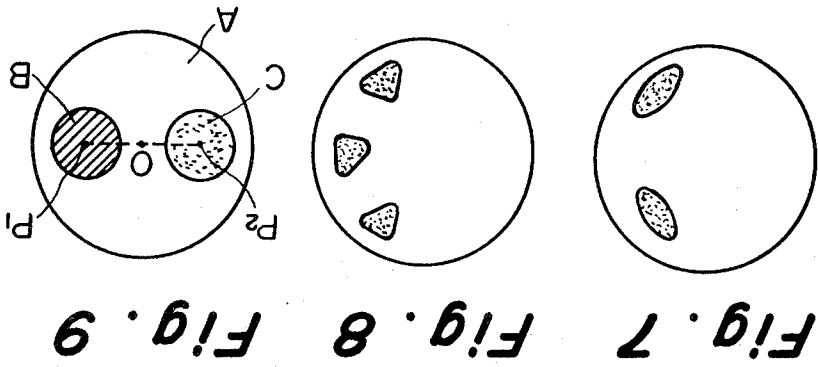
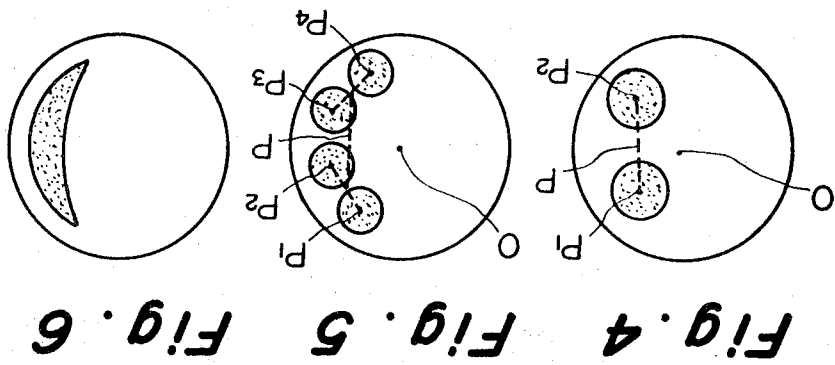
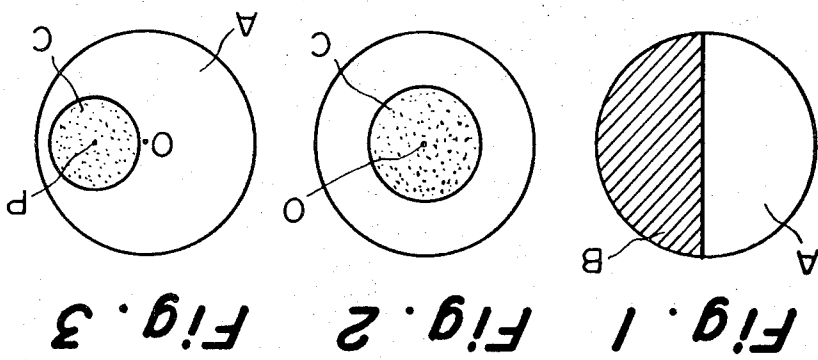
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[57] ABSTRACT

Composite filament having an elastic crimping property, comprised of at least two components disposed in an eccentric sheath-core relation along the longitudinal axis of the filament, in which one component is composed of a polyester consisting mainly of polyethylene terephthalate and another component or components comprise highly shrinkable polyamide having a shrinking percentage of 15–80 percent and the percent by weight of the core or cores in the filament is 5–50. It is preferable that the core component is composed of the polyester and the sheath component is composed of the polyamide. Furthermore, the eccentricity of the sheath-core relation is preferably at least 5. The core component may be constituted with a plurality number of cores.

18 Claims, 15 Drawing Figures





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Fig. 10 Fig. 11 Fig. 12

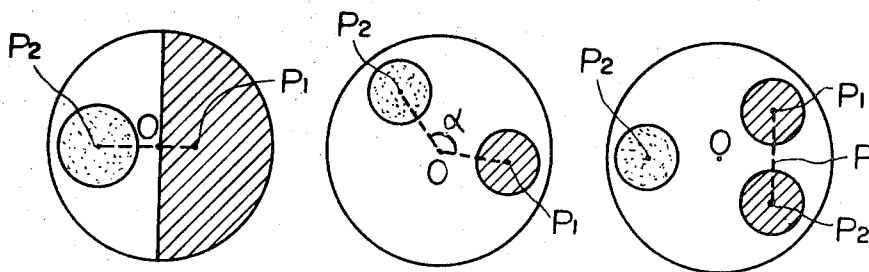
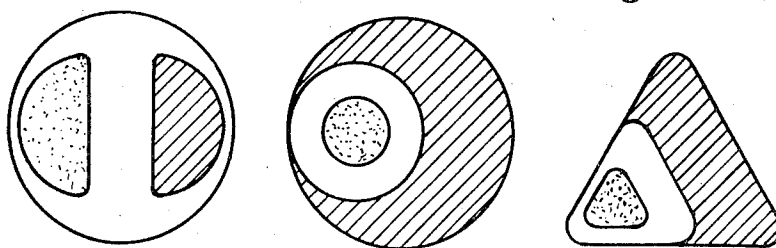


Fig. 13 Fig. 14 Fig. 15



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COMPOSITE FILAMENTS HAVING AN ELASTIC CRIMPING PROPERTY

The present invention relates to novel synthetic filaments, particularly to composite filaments having a high crimpability, an improved crimp elasticity and an excellent dyeability.

It has heretofore been well known that when different synthetic linear polymers are melted and conjugate spun simultaneously through common orifices in a sheath-core relation along the axial direction of the unitary filament, and the resulting filaments are drawn and subjected to shrinking treatment, then composite filaments having three-dimensional spiral crimps can be obtained.

Recently, a number of proposals have been made with respect to composite filaments having such three-dimensional crimp developability. For example, it has been known that as two polymer components constituting composite filaments, different homopolyamides, a homopolyamide and a copolyamide, different homopolyesters and a homopolyester and a copolyester are used in view of mutual adhesivity, conjugate spinnability and drawability, and the two polymers are bonded in a side-by-side relation as shown in FIG. 1, and composite filaments having a crimp developability are manufactured by the use of the difference between the shrinkabilities of both the polymers.

However, in these filaments, it is very difficult to improve properties other than crimping property, because two kinds of polymers constituting the composite filament have very similar chemical and physical properties.

That is, the polyamide composite filament has poor crimp elasticity, resilient crimpability and crimp bulkiness. While, the polyester composite filament has excellent crimp elasticity, but has insufficient crimp durability because of its poor recovering properties for elongation, bending and compression.

Furthermore, polyamide-polyester composite filaments are known, wherein a homopolyester component is arranged in the core portion and a homopolyamide component is arranged in the sheath portion eccentrically to the core portion in order to compensate mutually the above-mentioned drawbacks in the polyamide composite filament and the polyester composite filament.

However, even when such composite filaments are subjected to a crimp developing treatment to develop three-dimensional crimps, it is difficult to develop desired crimps, because the difference of shrinkability between the homopolyester component and the homopolyamide component constituting the composite filament is small, and they are arranged in a sheath-core relation. Moreover, when the sheath-core-type composite filaments of polyamide-polyester obtained by a conventional conjugate spinning process are subjected to a shrinking treatment to develop crimps, the excellent crimp elasticity of the polyester component cannot be developed fully on the whole filament, because the polyester component having elastic property is arranged in the inside portion of the crimps. Moreover, as the polyester component having poor recovering property for elongation is arranged in the inside portion of the crimps, the composite filament does not easily recover the original state, after applied mechanical stresses, such as repeating elongations, bendings, compressions, etc. Therefore, a desirable crimp durability cannot be obtained in the conventional sheath-core-type composite filament of polyamide-polyester.

Furthermore, conventional composite filaments have only latent crimpability and do not develop spontaneous crimps even if the conjugate spun filaments are relaxed after drawing and they are linear as in usual monofilament and develop three-dimensional crimps only after they are subjected to shrinking treatments, such as hot water treatment and dry heat treatment. Furthermore, when the composite filaments having the above-mentioned latent crimpability are knitted or woven into textures, such as stockings, socks, tricots and carpets, and then the resulting textures are directly subjected to a crimp developing treatment, tension and contact interference

between mutual filaments in the texture suppress the crimp developability considerably and develop considerably nonuniform crimps to form unevenness on the surface of the texture. In order to obviate such disadvantages in the crimp developing treatment after knitting or weaving, drawn composite filaments are generally subjected to a pretreatment, by which the drawn composite filaments are twisted or passed through a particular heater under tensionless state to develop preliminary crimps, and then led to various knitting or weaving steps.

It has been now surprisingly found that by obeying to novel critical combination components and their nature, of physical characteristics of such components and of certain new relationship thereof in the structure of the composite filament, novel and useful composite filaments having latent crimpability and solved conventional various drawbacks completely can be obtained.

The object of the present invention is to provide a sheath-core-type composite filament of polyamide-polyester having a high crimp developability, which has never been attained in the conventional sheath-core-type composite filament, by using a highly shrinkable polyamide as the polyamide component to make a difference of shrinking percentage between the polyamide component and the polyester component larger, and further selecting the conjugate ratio of the polyester component and the degree of the eccentricity of core component corresponding to the shrinking percentage of the polyamide component.

Another object of the present invention is to provide a composite filament having an excellent crimp elasticity and crimp recovering property, even when the filament is applied to mechanical stresses, such as repeating elongations, compressions and bendings, in said composite filament, a polyamide component having an excellent recovering property for elongation being located in the inside portion of the crimps and a highly elastic polyester component being located in the outside portion of the crimps, when the composite filament is subjected to a shrinking treatment to develop crimps.

Further object of the invention is to provide a composite filament having an excellent spontaneous crimpability which has never been seen in the conventional filament, that is, a novel composite filament capable of developing crimps spontaneously only by relaxing the drawn filament.

Other objects of the invention will be more apparent from the following description.

That is, the present invention provides a composite filament having an elastic crimping property. Wherein at least two different synthetic linear polymers are bonded in a sheath-core relation along the longitudinal direction of the unitary filament, characterized in that one polymer component is composed of a polyester consisting mainly of polyethylene terephthalate and another polymer component is composed of a highly shrinkable polyamide having a shrinking percentage in boiling water of at least 15 percent, that both the polymer components are arranged eccentrically in the cross section of the unitary filament, and that the core component occupies 10-50 percent by weight in the unitary filament.

It is necessary that the above-mentioned polyamide to be used in the present invention has a shrinking percentage in boiling water of 15-80 percent, preferably at least 20 percent. When the shrinking percentage is less than 15 percent, a satisfactory crimp is formed with difficulty and the shrinking percentage is preferable to be higher, but when the shrinking percentage is more than 80 percent, the commercial production cannot be effected.

The shrinking percentage is determined by the following manner.

The spun and drawn filaments are dipped in boiling water at 100° C. for 15 minutes under a load of 0.5 mg./d. and are shrunk. The shrinking percentage is shown by the percentage of apparent loss of the length calculated by the following formula:

$$\text{Shrinking percentage} = \frac{l_0 - l_1}{l_0} \times 100 (\%)$$

, wherein l_1 designates the length of the shrunk filament and l_0 the length of the original filament.

Generally speaking, ordinary homopolyamides have a shrinking percentage in boiling water of less than 15 percent, but high molecular weight homopolyamides having an intrinsic viscosity $[\eta]$ of more than 1.15 in m-cresol at 30° C. have a shrinking percentage in boiling water of more than 15 percent, and can be used in the present invention.

The most preferable highly shrinkable polyamides are copolyamide. That is, when the minor component of copolymerization in the copolyamide filament consisting of at least two polyamide-forming components is at least 5 percent by weight, the shrinking percentage in boiling water of the filament reaches usually more than 20 percent. While, when the major component of copolymerization is more than 95 percent by weight, it is preferable to increase the molecular weight of the copolyamide as in the case of the above-mentioned homopolyamides, otherwise in many cases the usual molecular weight of such copolyamides show the similar low shrinking percentage to conventional homopolyamides, such as polycapromide or polyhexamethylene adipamide previously used and having an ordinary viscosity. Therefore, the difference of shrinking percentage in boiling water between the copolyamide component and the polyester component (usually 10–13 percent) is not sufficient, and it is difficult to obtain composite filaments having a desired crimpability. Furthermore, it is not preferable that for the purpose of increasing the difference of the shrinking percentage in boiling water between the copolyamide component and the polyester component, the amount of the minor component in the comonomers constituting the copolyamide component is extremely increased. Because, the melting point, crystallinity, heat resistance, strength, initial modulus, etc., of the copolyamide decrease. In general, the amount of polyamide-forming minor component in the copolyamide should adopt such a value that the difference of the shrinking percentage from the polyester component is increased to the above necessary extent, within the range of at most 30 percent by weight, preferably at most 20 percent by weight.

For a better understanding of the invention, reference is taken to the accompanying drawings, wherein

FIG. 1 is a cross-sectional view, in an enlarged scale, of a conventional side-by-side-type composite filament,

FIG. 2 is a cross-sectional view, in an enlarged scale, of a conventional concentric sheath-core-type composite filament,

FIG. 3 is a cross-sectional view, in an enlarged scale, of a monocoar eccentric sheath-core-type composite filament according to the invention,

FIG. 4 is a cross-sectional view, in an enlarged scale, of an eccentric sheath-core-type composite filament according to the invention, wherein two separate cores are embedded eccentrically in the sheath,

FIG. 5 is a cross-sectional view, in an enlarged scale, of an eccentric sheath-core-type composite filament according to the invention, wherein four cores are embedded eccentrically in the sheath,

FIG. 6 is a cross-sectional view, in an enlarged scale, of a sheath-core-type composite filament according to the invention, wherein a core having a noncircular cross section is disposed eccentrically in the sheath,

FIGS. 7 and 8 are cross-sectional views, in an enlarged scale, of sheath-core-type composite filaments according to the invention, wherein at least two cores having a noncircular cross section are disposed eccentrically in the sheath, and

FIGS. 9–15 are cross-sectional views, in an enlarged scale, of embodiments of composite filaments according to the invention, which are composed of three different components.

The present invention provides sheath-core-type composite filaments arranged highly shrinkable polyamide not used in the past and polyester eccentrically in the cross section of the unitary filament. Such composite filaments, when merely relaxed after spinning and drawing, develop spontaneous crimps, the inside portion of which is located by the polyamide

component having a high recovering property for elongation. Moreover, when the composite filaments having the above-mentioned spontaneous crimps are subjected to a shrinking treatment, latent crimps are further developed remarkably along the crimp direction of the spontaneous crimps. Furthermore, in these filaments, the polyamide component having an excellent recovering property for elongation locates in the inside portion of the crimps and the polyester component having a high modulus of elasticity locates in the outside portion of the crimps, and consequently composite filaments having a high crimpability, improved crimp durability and crimp elasticity, which have never been obtained, can be easily obtained.

In order to attain the object of the present invention, it is preferable to select the degree of eccentricity of the core component depending upon the shrinking percentage of the polyamide component to be used so as to satisfy the following formulae:

$$\begin{aligned} 3.8 &\leq (1.4a^2 + 50b + 200\sqrt{c}) \times 10^{-3} \leq 7.0 \\ 80 &\geq a \geq 15 \text{ and } 10 \leq c \leq 50 \end{aligned} \quad (1)$$

, wherein a represents a shrinking percentage (%) of the polyamide component, b represents percentage (%) of eccentricity of the center of gravity (P) of core component positioned in the cross section of the unitary filament against the radius of the unitary filament, and c represents percent by weight of the core component in the unitary filament, at the same time.

In the above formulae, the percentage of eccentricity b shows a measure of the degree of eccentricity of the core portion and is shown in the following way.

When the distance between the center (O) of the filament and the center of gravity (P) of the core component is OP in the unitary filament, and the radius of said unitary filament is r , then the percentage of eccentricity b is shown by the ratio (%) of OP/ r .

The percentage of eccentricity is preferably at least 5.

In the composite filament shown in FIG. 2, the percentage of eccentricity b is 0 (%). In the composite filaments of the present invention, the number of cores in the cross section of the unitary filament is not always one, but may be plural as shown in FIGS. 4 and 5. In the filament shown in FIG. 4, the center of gravity (P) of the core components lies at the center of the straight line connecting the centers of gravity P1 and P2 of respective cores. In the filament shown in FIG. 5, the center of gravity (P) can be determined in the same manner. The cross-sectional shape of the core component is not always circular, but may be noncircular as shown in FIGS. 6–8.

In the present invention, the amount occupied by the core component in the unitary filament is 10–50 percent by weight, preferably 20–40 percent. When the amount is less than 10 percent by weight, it is difficult to obtain a composite filament having a desired crimpability and crimp elasticity. While, when the amount is more than 50 percent by weight, the percentage of eccentricity of the core component in the cross section of unitary filament is too small, and it is difficult to obtain a highly crimpable composite filament.

The composite filament according to the invention is particularly useful, when the shrinking percentage a of the polyamide component to be used, the percentage of eccentricity b of the core component and the percent by weight c of the core component in the unitary filament satisfy the relation shown by the above-mentioned formulae.

The most useful composite filament in the present invention is multicore filaments, in which the core component locating in the cross section of the filament consists of two or more cores composed of a polyester and the sheath component consists of a highly shrinkable polyamide, and further the above-mentioned formulae (1) and the following formulas (2)

$$\begin{aligned} 1.2 \times 10^{-1} &\leq NS \left(\frac{D}{R} \right)^2 (1 + E) \leq 10.1 \times 10^{-1} (N \geq 2) \\ E &\geq 0.1 \text{ and } S \geq 1.1 \end{aligned} \quad (2)$$

, wherein D represents an arithmetic mean of diameters of each core, when the cores are circular and when the cores are noncircular, D represents arithmetic mean of diameters of circles, when said noncircular cores are calculated into circles, R diameter of the unitary filaments, N number of cores, and E and S ratio of initial modulus and ratio of heat shrinkability of the polyamide based on the polyester respectively, are satisfied at the same time.

In the above-mentioned formulas (2), $N(D/R)^2$ represents a ratio (by weight) of the core component based on bonded total component. Furthermore, if the initial moduli and heat-shrinkabilities of the polyester and the polyamide are expressed by E_e , E_n , and S_e , S_n , respectively, the ratio of initial modulus and the ratio of heat-shrinkability in the formulas (2) are shown by $E=E_n/E_e$ and $S=S_n/S_e$. For example, when the polyamide used has a low initial modulus, the ratio E of initial modulus of the polyamide based on the polyester is less than 0.1, and even if such composite filament is subjected to a crimp developing treatment, the crimp recovering property and crimp elasticity of the developed crimps are not satisfactory. While, in the case of the ratio of heat-shrinkability S being less than 1.1, even if the drawn filament is relaxed, the spontaneous crimpability is poor, and further the curliness after a crimp developing treatment is extremely low. Therefore, composite filaments having such a low crimpability are not suitable for the present invention.

Another preferable composite filament capable of attaining the object of the present invention is one, wherein the highly shrinkable polyamide component composing the filament consists of a homopolyamide component and a copolyamide component which form distinct filamentary components and are bonded along the filament axis, and further a core composed of a polyester component is embedded in said homopolyamide component without contacting with the above-mentioned copolyamide component.

That is, such a composite filament is characterized in that said core component is composed of a polyester consisting mainly of polyethylene terephthalate, and said sheath component is composed of at least two highly shrinkable polyamide components, a homopolyamide component having substantially homogeneous composition and a copolyamide component being arranged eccentrically in the cross section of the unitary filament, that said polyester component occupies 10-50 percent by weight in the unitary filament, and that said polyester component locates in said homopolyamide component without contacting with said copolyamide component under such a condition that the lesser angle α formed by two straight lines, one of which connects the center of gravity of said polyester component with the center of the filament and the other of which connects the center of gravity of said copolyamide component with the center of the filament, in the cross section of the unitary filament, is between 90° and 180° .

The bonding configuration of the above-mentioned three components, i.e., copolyamide, homopolyamide and polyester in the cross section of the composite filament of the present invention is shown, for example, by FIGS. 9-15, and the fundamental bonding configuration is shown by FIGS. 9 and 10.

That is, in the filament shown in FIG. 9, the copolyamide component (hereinafter referred to as "component B") and the polyester component (hereinafter referred to as "component C") are arranged in the core portion, and the homopolyamide component (hereinafter referred to as "component A") is arranged in the sheath portion, and three components A, B and C are arranged eccentrically to each other. Furthermore, in FIG. 10, the component A and the component B are arranged in a side-by-side relation and the component C is arranged eccentrically to the component B as a core. The feature of the present invention lies in that the component C is surrounded by the component A in both the filaments shown in FIGS. 9 and 10. However, when the component C is surrounded by the component B, a composite filament having an excellent crimpability cannot be obtained. That is, when such a composite filament is subjected to a crimp developing treatment, the composite filament develops

crimps, in which the polyester component locates in the inside portion of crimps as in the case of conventional polyester-polyamide core-sheath composite filaments. Consequently, the contribution of the modulus of elasticity of the polyester component to the total crimps is small, and further as the polyester component having poor recovering property for elongation locates in the inside portion of the crimps, such a filament is insufficient in the crimp recovering properties and crimp durabilities for mechanical stresses, such as repeating elongations, bendings and compressions.

The most important characteristics of the present invention lie in that the polyester component is arranged in a defined relation against the polyamide component. This defined arrangement will be explained with reference to drawings.

As shown in FIG. 11, it is necessary that the copolyamide component and the polyester component are arranged in the cross section of the unitary filament so as to satisfy such a condition that the lesser angle α formed by two straight lines P_1O and P_2O (the angle is hereinafter referred to as eccentric angle), one of which connects the center of gravity P_1 of the copolyamide component with the center O of the filament and the other of which connects the center of gravity P_2 of the polyester component with the center O of the filament, is between 90° and 180° . The bonding configurations shown in FIGS. 9 and 10 have an eccentric angle of $\alpha=180^\circ$.

FIG. 12 shows an embodiment, wherein the polyester component forms one core and the copolyamide component forms two cores. The center of gravity (P) of the copolyamide component lies at the center of the straight lines P_1P_2 connecting respective centers of gravity P_1 and P_2 . When the eccentric angle α exceeds the above-mentioned range, that is, $\alpha \leq 90^\circ$, the copolyamide component and the polyester component are too closely arranged, and it is difficult to attain the object of the invention. The cross-sectional configurations of the above-mentioned three components and the unitary filament of the composite filament of the present invention may be noncircular as shown in FIGS. 13-15.

When the above-mentioned highly shrinkable polyamide components are composed of two components of a homopolyamide component and a copolyamide component, the amount of the above-mentioned homopolyamide component occupied in the unitary filament is within the range of at least 20-80 percent by weight, preferably 30-80 percent by weight, and the amount of the above-mentioned copolyamide component is within the range of 8-70 percent by weight, preferably 10-50 percent by weight. When the amount of the homopolyamide component is less than 20 percent by weight, or the amount of the copolyamide component is more than 70 percent by weight, the area occupied by the copolyamide component in the cross section of the unitary filament is too large, and various disadvantages owing to the use of copolyamide occur, and particularly, initial modulus, heat resistance and light resistance decrease. While, when the amount of the homopolyamide component is more than 80 percent by weight, the amount of the copolyamide component reduces considerably, and a composite filament having a desired crimpability cannot be obtained.

The composite filament according to the present invention can be spun by means of conventional spinning process and apparatus.

Furthermore, the drawing can be effected without the use of special process and apparatus, and effected by means of the exactly same process and apparatus as conventionally used. For example, cold drawing at room temperature or hot drawing by means of a hot drawn pin or hot draw rollers heated at $60-180^\circ\text{C}$. can be used.

The polyester component to be used in the present invention is polyesters consisting mainly of polyethylene terephthalate, and includes copolyesters of main component of polyethylene terephthalate with other polyesters, such as polyethylene isophthalate, polytetramethylene terephthalate, polyethylene oxybenzoate, polyethylene hexahydroterephthalate, etc. However, in the above-mentioned copolyester, the

amount of minor component of the copolymerization is preferably less than 5 percent by weight, and when the amount of such minor component exceeds 5 percent by weight, the melting point, crystallinity and yarn property, particularly modulus of elasticity reduce due to the copolymerization and further the crimpability decreases owing to the increase of heat-shrinkability.

As the homopolyamide component having substantially homogeneous composition to be used in the present invention, mention may be made of homopolyamides obtained by polymerizing cyclic lactams, such as caprolactam, enantholactam, lauryllactam and the like, or nylon salts of diamines, such as tetramethylenediamine, hexamethylenediamine, undecamethylenediamine, m-xylylenediamine, p-xylylenediamine, bis-(p-aminocyclohexyl)methane and the like, with dicarboxylic acids, such as adipic acid, sebacic acid, dodecanedicarboxylic acid, isophthalic acid, hexahydroterephthalic acid and the like. Furthermore, as the highly shrinkable copolyamide component, mention may be made of copolyamides obtained by copolymerizing at least two conventional polyamide-forming components including the above-mentioned cyclic lactams and nylon salts.

The composite filament according to the present invention has a merit that when the filament is unwound from a bobbin and relaxed, it develops uniform spontaneous crimps having a spiral three-dimensional structure which have never been developed in the conventional composite filament. Furthermore, when such spontaneously crimped filament is subjected to shrinking treatments, such as swelling, wetting and heating, latent crimps are added in addition to the spontaneous crimps and extremely high crimps are formed. Therefore, when the composite filaments according to the invention are made into various knitted goods, woven fabrics and pile articles, even if the filaments obtained by conjugate spinning and drawing are directly subjected to a knitting step or a weaving step without pretreatment, which is necessary for the conventional filaments, crimped products having an extremely excellent quality and peculiar properties can be obtained. Moreover, when the composite filament is subjected to a crimp developing treatment, the filament develops crimps, in which the polyester component having an excellent elastic property locates in the outside portion and the polyamide component having an excellent recovering property for elongation locates in the inside portion, and therefore a crimped filament having an excellent crimp elasticity and crimp recovering property and further having a high bulkiness, stretchability and durability similar to those of wool can be obtained.

The composite filament according to the invention can be used in a wide field not only for garments but also for industrial materials and interior ornaments in the form of continuous filaments or staple fibers.

The invention will be explained in more detail with reference to the following examples.

Crimping properties and dyeability shown in the following examples are determined as follows.

1. Spontaneous curliness:

The bundle of 30 drawn filaments having a length of 30 cm. is applied to a load of 0.1 mg./d. The spontaneous curliness is shown by the percentage of apparent loss of the length calculated by the following equation.

$$\text{Spontaneous curliness} = \frac{l_0 - l_2}{l_0} \times 100 (\%)$$

, wherein l_2 designates the length of the spontaneously crimped filament under the load of 0.1 mg./d. and l_0 the

original length of the filament in the drawn state.

2. Total curliness:

The bundle of 30 drawn filaments having a length of 30 cm. is dipped in boiling water for 10 minutes under a load of 0.1 mg./d. and then air-dried under the same load. The total curliness after crimp developing treatment is shown by the percentage of apparent loss of the length calculated by the following equation.

$$\text{Total curliness} = \frac{l_0 - l_3}{l_0} \times 100 (\%)$$

, wherein l_3 designates the length of the crimped filament and l_0 the original length of the filament in the drawn state.

3. Crimp elasticity:

The crimp elasticity is shown by the load (mg./d.) required for stretching the length of the crimped composite filament bundle obtained in paragraph (2) (under a load of 0.1 mg./d.) to 120 percent.

4. Crimp recovering percentage for elongation:

The length of the filament, when the crimped composite filament bundle in the above paragraph (2) is applied a load of 0.2 mg./d., is l_0 and, the length, when a load of 0.1 g./d. is further added for one minute, is l_4 and then the length, 2 minutes after removed the load of 0.1 g./d., is l_5 .

5. Crimp recovering percentage for elongation (%)

$$= \frac{l_5 - l_0}{l_4 - l_0} \times 100$$

5. Crimp recovering percentage for compression:

The crimped composite filaments obtained in the above paragraph (2) are cut into a length of 2 cm., 20 g. of which are introduced into a measuring cylinder having a diameter of 5 cm., and then a piston of 200 g. weight mounts on the crimped composite filaments and thereafter said measuring cylinder is subjected to a fine vibration and the equilibrium position of the piston is read (the height is l_0).

Then, a load of 600 g. is further applied to said piston and the equilibrium position of the piston is read in the same manner as described above (the height is l_6). Thereafter, only said load of 600 g. is removed whereby the position of the piston is recovered naturally and after 5 minutes the height is read (the height is l_7).

The crimp recovering percentage for compression (%)

$$= \frac{l_7 - l_0}{l_6 - l_0} \times 100$$

6. Dyeability:

Into a dye bath prepared by dissolving 0.03 g. of acid dye, Coomassie Ultra Sky SE (manufactured by I. C. I. Co.) in 50 cc. water is dipped 1 g. of drawn filament, and 0.03 g. of glacial acetic acid is added thereto. Then, the assembly is heated from room temperature to 95° C. in 30 minutes and maintained at the same temperature for 30 minutes. The percentage of dye absorbed shows the dyeability (%).

EXAMPLE I

Polyethylene terephthalate having an intrinsic viscosity $[\eta]$ of 0.63 in o-chlorophenol at 30° C. and polycapromide-polyhexamethylene isophthalamide copolymer (hereinafter abridged as 6/6I) with a predetermined copolymerization ratio having an intrinsic viscosity $[\eta]$ of 1.02 in m-cresol at 30° C. were melted and conjugate spun at a temperature of 285° C. in an eccentric sheath-core relation, in which polyethylene terephthalate formed a core and 6/6I copolymer formed a sheath, in a conjugate ratio (by weight) of 1:3 by means of a conventional conjugate spinning apparatus, and then the

TABLE I

Sample No.	Copolymerization ratio of 6/6I (by weight)	Kind of composite filament	Shrinking percentage of mono-filament (percent)	Strength (g./d.)	Elongation (percent)	Initial modulus (g./d.)
1	100/0	Conventional composite filament	12	4.8	32	35
2	99/1	Composite filament beyond the scope of the present invention	13	4.8	31	36
3	95/5	Composite filament of the present invention	23	4.7	34	34
4	90/10	do	34	4.7	30	35
5	80/20	do	50	4.4	35	31
6	75/25	Composite filament beyond the scope of the present invention	62	3.8	38	25

resulting filaments were cold drawn 3.7 times their original length at room temperature to obtain drawn composite filaments of 70 d./18 f.

An enlarged cross section of this filament had a bonding configuration as shown in FIG. 3, in which an eccentricity *b* of polyethylene terephthalate of the core portion was 50 percent.

Yarn qualities of the composite filaments are shown in Table 1.

Furthermore, the results of crimp property measured with respect to the above-described composite filaments are shown in Table 2.

TABLE 2

Sample No.	Spontaneous curliness (percent)	Total curliness (percent)	Crimp elasticity, mg./d.	Crimp recovering percentage for elongation (percent)	Crimp recovering percentage for compression (percent)
1.....	2	25	---	76	66
2.....	8	38	---	79	69
3.....	21	52	4.6	86	78
4.....	28	63	7.0	87	82
5.....	32	81	8.1	84	80
6.....	35	85	7.3	76	71

Concerning the above-described crimped filaments Nos. 1-6, the position of polyethylene terephthalate of the core component in the cross section of the filament was checked by means of a polarizing microscope, and as the result polyethylene terephthalate in Nos. 1 and 2 located in the inside portion of the crimp, while the polyester in Nos. 3 to 6 located in the outside of the crimp. Filaments Nos. 1 and 2 did not develop spontaneous crimps, when they were drawn and relaxed, but filaments Nos. 3 to 5 developed spontaneous crimps when they were drawn and relaxed in crimped filaments thereof the total curliness was large, and the crimp elasticity and crimp recovering percentage were excellent. Filament No. 6 was poor in the yarn quality as shown in Table 1 and therefore had poor crimp elasticity and crimp recovering properties, even though such a filament developed spontaneous crimps and had an excellent total curliness.

EXAMPLE 2

The same polyethylene terephthalate as used in Example 1 and polyhexamethylene adipamide-polycapraamide copolymer having an intrinsic viscosity $[\eta]$ of 1.13 in *m*-cresol at 30° C. (copolymerization ratio of 66/6=90/10) were melted and conjugate spun at a temperature of 285° C. in a predetermined conjugate ratio as shown in Table 3 by means of a conventional sheath-core-type conjugate spinning apparatus, and then the resulting filaments were drawn 3.9 times their original length on a draw pin heated at 80° C. to obtain drawn composite filaments of 70 d./18 f.

The obtained composite filament had a bonding configuration as shown in FIG. 7, in which two elliptical polyester core components existed in the eccentricity of 30 percent.

On the other hand, copolyamide constituting the sheath portion of the composite filament was spun solely and the shrinking percentage of the resulting filament was measured and was 30 percent.

Yarn quality and crimp property of each composite filament are shown in Table 3.

As seen from Table 3, in the filament No. 8 having a small content of polyethylene terephthalate (polyester component), a satisfactory crimp property was not obtained. On the contrary, in the filaments Nos. 9 and 10, the content of the polyester component was within the scope of the present invention and all formulas to be applied to the present invention were satisfied, so that these filaments showed an excellent crimp property. In the filament No. 11, the content of the polyester component was larger than that of polyamide component, so that the dyeability for an acid dyestuff considerably lowered and such a filament was not used practically.

TABLE 3

Sample No.	Kind of composite filament	Weight percentage of polyethylene terephthalate in mono-filament (percent)		Yarn quality		Total curliness after shrinking treatment (percent)	Crimp recovering percentage for elongation (percent)	Crimp recovering percentage for compression (percent)	Dyeability (percent)
		Strength (g./d.)	Elongation (percent)	Initial modulus (g./d.)	Elongation (percent)				
7.....	Composite filament for control	4.5	23	25	37	75	71	94	94
8.....	Composite filament beyond the scope of the invention	4.7	24	35	42	87	82	87	87
9.....	Composite filament of the invention	4.8	21	42	61	92	88	70	70
10.....	do	4.8	22	61	67	79	73	53	53
11.....	Composite filament beyond the scope of the invention	4.8	20	77	67	71	73	31	31

TABLE 4

Sample No.	Kind of composite filament	Eccentricity (percent)	Spontaneous curliness (percent)	Total curliness (percent)	Crimp elasticity (mg./d.)	Crimp recovering percentage for elongation (percent)	Crimp recovering percentage for compression (percent)
12.....	Filament beyond the scope of the invention.....	10	9	39	7.1	67	60
13.....	Filament of the present invention.....	20	21	57	10.7	79	74
14.....	do.....	25	28	63	11.2	84	78
15.....	do.....	35	41	85	13.4	87	81
16.....	do.....	40	50	91	15.0	90	83

EXAMPLE 3

The same polyethylene terephthalate as used in Example 1 and a copolyamide having an intrinsic viscosity $[\eta]$ of 1.08 in m-cresol at 30° C. which was obtained by reacting caprolactam with a salt of N,N'-bis(γ -aminopropyl) piperazine and adipic acid in a weight ratio of 92/8, were conjugate spun in a sheath-core relation in which polyethylene terephthalate was a core component and copolyamide was a sheath component, at a temperature of 285° C. by means of the apparatus used in Example 1 in a conjugate ratio (by weight) of 30:70. In this case, the eccentricity of polyethylene terephthalate arranged in a form of circle in the core portion was changed variously. Then, the resulting filaments were drawn 3.9 times their original length at room temperature to obtain drawn composite monofilaments of 15 d.

Furthermore, the above described copolyamide was spun solely and drawn to obtain a control filament, the shrinking percentage of which was 35 percent.

Crimp properties of the obtained composite filaments are shown in Table 4.

As seen from Table 4, the filaments Nos. 13 to 16 having an eccentricity preferable for the present invention were extremely superior in crimpability, crimp elasticity and crimp recovering properties to the filament No. 12.

EXAMPLE 4

The same polyethylene terephthalate as used in Example 1 and three kinds of polyamides having various intrinsic viscosities as shown in the following Table 5 were melted and conjugate spun in such a sheath-core relation that the polyester component was arranged in the sheath portion and the polyamide component was arranged in the core portion, at a temperature of 285° C. in a conjugate ratio (by weight) of 3:1 by

TABLE 5

Polyamide	Intrinsic viscosity $[\eta]$	Shrinking percentage of monofilament in hot water (percent)
A..... Nylon-6.....	0.95	11.3
B..... do.....	1.08	13.1
C..... do.....	1.25	15.4
D..... 6/66 copolymer (97/3).....	0.95	12.4
E..... do.....	1.08	14.2
F..... do.....	1.25	18.3
G..... 6/66 copolymer (90/10).....	0.95	24.2
H..... do.....	1.08	28.6
I..... do.....	1.25	35.1

TABLE 6

Sample No.	Polyamide	Kind of composite filament	Spontaneous curliness (percent)	Total curliness (percent)	Crimp elasticity (mg./d.)	Crimp recovering percentage for elongation (percent)	Crimp recovering percentage for compression (percent)
17.....	A	Conventional composite filament.....	1	21	-----	11	9
18.....	B	do.....	4	29	-----	13	10
19.....	C	Composite filament of the present invention.....	18	43	16.6	48	36
20.....	D	Composite filament beyond the scope of the invention.....	2	25	-----	16	12
21.....	E	do.....	13	31	12.9	21	18
22.....	F	Composite filament of the present invention.....	26	57	17.4	65	47
23.....	G	do.....	29	61	20.0	68	51
24.....	H	do.....	31	65	22.9	75	58
25.....	I	do.....	38	73	24.3	79	64

means of the conjugate spinning apparatus of Example 1, and then the resulting filaments were drawn 4.2 times their original length on a draw pin heated at 90° C. to obtain drawn composite filaments of 70 d./18 f. respectively.

Enlarged cross sections of these composite filaments had respectively bonding configurations as shown in FIG. 3, in which the eccentricity b of the polyamide component of the core portion was 50 percent.

Crimp properties of the composite filaments thus obtained are shown in Table 6.

Concerning the crimped filaments Nos. 17 to 25 after shrunk, the position of the polyamide component in the cross section was checked by means of a polarizing microscope. In the filaments Nos. 17, 18, 20 and 21, the polyamide located in the outside portion of the crimp. Therefore, the polyester component having poor recovering property for elongation located mainly in the inside portion of the crimp, so that the crimp recovering property after elongation or compression was poor. On the other hand, in the composite filaments Nos. 19 and 22-25 of the present invention containing high shrinkable polyamide in the core portion, the polyamide component located in the inside of the crimp, so that the crimp recovering property was considerably high and crimpability was good.

EXAMPLE 5

Polyethylene terephthalate having an intrinsic viscosity of 0.65 in o-chlorophenol at 30° C. and nylon-6 having an intrinsic viscosity of 1.15 in m-cresol at 30° C. were melted and conjugate spun in an eccentric sheath-core relation, in which the polyethylene terephthalate formed the core and the nylon-6 formed the sheath, at a temperature of 285° C., the ratio $N(D/R)$ of the core component to the total bonded components being 0.05, 0.10, 0.25, 0.40 and 0.5, and then the resulting filaments were cold drawn 3.79 times their original length to obtain drawn composite filaments of 70 d./18 f., which had a cross section as shown in FIG. 4. In this case, the difference between heat shrinking percentages in both components was 50 percent, i.e., $S=1.5$.

Strength, elongation, dyeability and crimp property after treatment for developing crimps in the obtained composite filaments are shown in Table 7.

As seen from Table 7, when $N(D/R)^2$ is less 0.10 within the scope of the present invention, the obtained composite filament is extremely low in the curliness after developed crimps. Further, as seen from the spontaneous curliness in Table 7, the particularly preferable two-core composite filament according to the present invention develops crimps immediately when it

TABLE 7

Sample No.	$N \left(\frac{D}{R} \right)^2$	1+E	S	$NS \left(\frac{D}{R} \right)^2 (1+E)$	Strength (g./d.)	Elongation (percent)	Spontaneous curliness (percent)	Total curliness (percent)	Crimp elasticity (mg./d.)	Crimp recovering percentage for elongation (percent)	Dyeability (percent)
Within the scope of the invention.....											
26	1	1.5	1.5	-----	30	4.72	26	70	12.3	75	60
Do.....	1	1.5	1.5	-----	60	4.90	29	68	10.5	73	73
27	1	1.5	1.5	-----	35	5.10	29	61	9.5	70	78
Beyond the scope of the invention.....											
28	1	1.5	1.5	-----	70	6.15	30	0	0	0	80
Do.....	2	1.5	1.5	-----	60	5.20	31	5	0	0	81
Within the scope of the invention.....											
31	2	0.45	1.5	1.01	20	4.68	28	75	15.9	93	69
Do.....	32	2	0.40	1.00	20	4.77	24	78	15.0	96	72
Do.....	33	2	0.25	0.62	45	4.91	28	76	14.5	93	75
Do.....	34	2	0.10	0.22	50	5.25	30	68	12.0	89	82

* The measurement is impossible, because the curliness is extremely low.

TABLE 9

Sample No.	Conjugate ratio (by weight) A:B:C	Kind of composite filament	Yarn quality			Spontaneous curliness (percent)	Total curliness		Crimp elasticity (mg./d.)	Crimp re-covering percentage for elongation (percent)	Dyeability (percent)
			Strength (g./d.)	Elongation (percent)	Initial modulus (g./d.)		0.1 mg./d.	1 mg./d.			
39	80:20:0	Conventional composite filament	4.7	34.2	18.1	0	41.1	19.3	0.6	54	92
40	75:20:5	Composite filament beyond the scope of the invention	4.7	31.5	20.3	8.2	44.8	23.1	1.1	59	85
41	70:20:10	Composite filament of the invention	4.6	35.2	27.6	17.4	51.3	33.9	3.6	65	80
42	60:20:20	do	4.7	34.3	41.2	23.8	58.2	44.0	6.1	69	67
43	30:20:60	do	4.7	31.0	59.4	38.9	62.7	49.1	7.7	74	54
44	20:20:60	Composite filament beyond the scope of the invention	4.5	35.6	67.0	41.3	64.1	50.7	7.9	73	38

TABLE 8

Sample No.	Eccentric angle α	Kind of composite filament	Spontaneous curliness (percent)	Total curliness (percent) (0.1 mg./d.)	Crimp elasticity (mg./d.)	Crimp recovering percentage for elongation (percent)
35.....	70°	Composite filament beyond the scope of the invention.				
36.....	100°	Composite filament of the invention.	9.5	21.4	0.8	58
37.....	140°	do.....	13.3	45.6	1.4	74
38.....	180°	do.....	15.7	49.9	1.7	79
			18.1	53.1	2.1	83

TABLE 10

Sample No.	Conjugate ratio (by weight) A:B:C	Copolymerization ratio of 66/610	Kind of composite filament	Spontaneous curliness (percent)	Total curliness (percent) (0.1 mg./d.)	Crimp elasticity (mg./d.)	Crimp recovering percentage for elongation (percent)
45.....	50:50:0	100/0	Conventional filament		11.2		
46.....	50:50:0	97/3	do.....		25.6		
47.....	50:50:0	95/5	do.....		25.6	0.1	58
48.....	50:50:0	90/10	do.....		38.4	0.3	61
49.....	50:50:0	80/20	do.....		67.1	0.5	63
50.....	35:50:15	100/0	do.....		70.2	0.9	66
51.....	35:50:15	97/3	Filament beyond the scope of the invention		24.7	0.5	56
52.....	35:50:15	95/5	Filament of the present invention	2.7	20.6	0.9	67
53.....	35:50:15	90/10	do.....	8.9	42.9	2.5	76
54.....	35:50:15	80/20	do.....	14.1	67.8	3.9	82
				17.6	80.8	5.5	87

is drawn and relaxed and such a filament shows an excellent crimp property after developed crimps.

Moreover, the parts showing no numerical value in $NS(D/R)^2(1+E)$ of Table 7 do not satisfy the range of the formula (2) according to the present invention.

EXAMPLE 6

Polyethylene terephthalate (C-component) having an intrinsic viscosity $[\eta]$ of 0.65 in o-chlorophenol at 30° C., polycaprolactam-polyhexamethylene adipamide copolymer (copolymerization composition of 6/66=80/20 weight ratio, B-component) having an intrinsic viscosity $[\eta]$ of 1.05 in m-cresol at 30° C. and polycaprolactam (A-component) having an intrinsic viscosity $[\eta]$ of 1.0 in m-cresol at 30° C. were melted and conjugate spun in an eccentric sheath-core relation, wherein the B-component and the C-component formed the cores and the A-component formed sheath, in a conjugate ratio (by weight) of A:B:C=80:10:10 at a temperature of 280° C. by means of a conventional conjugate spinning apparatus, and then the resulting filaments were cold drawn 3.8 times their original length to obtain drawn composite filaments of 70 d./18 f.

An enlarged cross section of this filament had a bonding configuration as shown in FIG. 11, in which an eccentric angle α between the B-component and the C-component of core portions were changed variously.

Crimp properties of the composite filaments having said various eccentric angles were measured and the results are shown in Table 8.

Concerning the crimped filaments Nos. 35-38, the position of the C-component, polyester in the cross section of the filament was checked by a polarizing microscope, and as the result the polyester in the filament No. 35 located in the inside of the crimp, while the polyester in the filaments Nos. 36-38 located in the outside of the crimp. Accordingly, in the filament No. 35 the spontaneous crimp was somewhat poor, the total curliness after a shrinking treatment was considerably low, and the crimp elasticity and recovering percentage for elongation were poor. On the contrary, in the crimp-developed composite filaments Nos. 36-38 according to the present invention, the total curliness after a shrinking treatment was particularly high and the crimp elasticity and recovering percentage for elongation were excellent.

EXAMPLE 7

Polyethylene terephthalate (C-component) and polycaprolactam (A-component) used in Example 6, and polycaprolactam-polyhexamethylene isophthalamide copolymer (copolymerization composition of 6/61=85/15 weight ratio, B-component) having an intrinsic viscosity $[\eta]$ of 1.13 in m-

cresol at 30° C. were melted and conjugate spun at a temperature of 280° C. in a predetermined conjugate ratio as shown in Table 9 by means of a conventional sheath-core-type conjugate spinning apparatus, and then the resulting filaments were drawn 3.9 times their original length on a draw pin heated at 80° C. to obtain drawn composite filaments of 70 d./18 f.

The obtained composite filament had a bonding configuration as shown in FIG. 13, in which the B-component and the C-component were semicircular cores, and the eccentric angle α was 180°.

Yarn quality, crimp property and dyeability of each composite filament are shown in Table 9.

As seen from Table 9, in the filaments Nos. 41 to 44 containing more than 10 percent of polyester component (C-component) with high elasticity, splendid spiral spontaneous crimps were developed when they were drawn and relaxed, and when these drawn filaments were subjected to a shrinking treatment, a tension due to a contact interference between mutual filaments by the spontaneous crimp was small, so that the extremely excellent crimps were developed, and particularly crimp developability under a high load was excellent.

Furthermore, in the composite filaments Nos. 41-43 of the present invention, it was found that crimp elasticity and recovery for elongation were excellent. In the filament No. 44 containing 60 percent of polyester component (C-component), crimp property was fairly good, but had a fault in point of dyeability for acid dye.

EXAMPLE 8

Polyhexamethylene adipamide (A-component) having an intrinsic viscosity $[\eta]$ of 1.02 in m-cresol at 30° C., polyhexamethylene adipamide-polyhexamethylene sebacamide copolymer (66/610, B-component) having an intrinsic viscosity $[\eta]$ of 1.12 and polyethylene terephthalate used in Example 6 (C-component) were melted and conjugate spun in a conjugate ratio (by weight) of A:B:C=35:50:15 at a temperature of 290° C. by means of a conventional conjugate spinning apparatus for three-component system, and then the resulting filaments were hot drawn 4.1 times their original length on a draw pin heated at 70° C. to obtain drawn composite monofilaments of 15 deniers.

The obtained composite monofilament had a bonding configuration as shown in FIG. 10, in which C-component was arranged as a core component in A-component, A-component and B-component were bonded in a side-by-side relation, and an eccentric angle α between B- and C-components was 180°.

For a comparison, the above described A- and B-components were conjugate spun in a conjugate ratio (by weight) of 1:1 by means of a conventional side-by-side-type conjugate spinning apparatus for two component system without using polyester of C-component and drawn under the same condi-

tions as described above to obtain drawn composite monofilament of 15 deniers having a bonding configuration as shown in FIG. 1.

Crimp properties of said composite filaments are shown in Table 10.

As seen from Table 10, conventional polyamide series composite filaments Nos. 45-49 did not develop spontaneous crimp at all and developed spiral latent crimps for the first time by a shrinking treatment. On the other hand, in the filaments Nos. 52-54 of the present invention containing high shrinkable copolyamide, spontaneous crimps were developed when such filaments were drawn and relaxed, and further the more excellent crimps were developed by a shrinking treatment, and also crimp elasticity and recovery for elongation were more excellent as compared with those of the conventional polyamide series composite filaments. In the filament No. 51, the shrinking percentage of B-component was not so high, so that the crimp property was poor as in the case of the filament No. 50.

What is claimed is:

1. A composite filament having elastic crimping property, comprising at least two components disposed in an eccentric sheath-core relation along the longitudinal axis of the filament, wherein

a. the first component is the core component composed of a polyester consisting essentially of polyethylene terephthalate; and

b. the second and any other components comprise the sheath of a highly shrinkable polyamide having a shrinking percentage of 15-85 percent;

the percent by weight of core component in the filament being 5-50; and the following conditions (1) and (2) being present at the same time:

(1) (i) $3.8 \leq (1.4a^2 \times 50b + 200 \sqrt{c}) \times 10^{-3} \leq 7.0$;

and

(ii) $B \geq 5$;

wherein a represents said shrinking percentage of the sheath component,

b represents the percentage of eccentricity of the center of gravity (P) of the core component positioned in the cross section of the filament against the radius of the filament,

and

c represents said percentage of the core component; and

(2) (i) $1.2 \times 10^{-1} \leq NS(D/R)^2(1+E) \leq 10.1 \times 10^{-1}$ ($N \geq 2$);

(ii) $E \geq 0.1$; and

(iii) $S \geq 1.1$;

wherein D is the arithmetic mean of diameters of each core, when the cores are circular, or when the cores are noncircular, is the arithmetic mean of diameters of circles, when said noncircular cores are calculated into circles,

R is the diameter of the filament,

N is the number of cores,

E is the ratio of initial modulus of the polyamide to the polyester, and

S is the ratio of heat shrinkability of the polyamide to the polyester.

2. The composite filament as claimed in claim 1, wherein said shrinking percentage is at least 20 percent.

3. The composite filament as claimed in claim 1, wherein said percent by weight of the core or cores in the filament is 20 ~ 40.

4. The composite filament as claimed in claim 1 which has at least two cores.

5. The composite filament as claimed in claim 1, wherein said polyamide is a homopolyamide having an intrinsic viscosity of at least 1.15.

6. The composite filament as claimed in claim 1, wherein said homopolyamide is nylon-6 or nylon-66.

7. The composite filament as claimed in claim 1, wherein said polyamide is a copolyamide of more than 95 percent by weight of a polyamide-forming constituent and less than 5 percent by weight of another polyamide-forming constituent and having an intrinsic viscosity of at least 1.15.

8. The composite filament as claimed in claim 1, wherein said polyamide is a copolyamide of 95 ~ 70 percent by weight of a polyamide-forming constituent and 5 ~ 30 percent by weight of another polyamide-forming constituent.

9. The composite filament as claimed in claim 1, wherein said polyamide is of poly(caproamide/hexamethylene adipamide), poly(caproamide/hexamethylene isophthalamide) or poly(hexamethylene adipamide/hexamethylene sebacamide).

10. The composite filament as claimed in claim 1, wherein the sheath is constituted with two polyamide components disposed eccentrically to each other in distinct zone with intimate adherent surface extending along the filament axis, one of said components consists of a homopolyamide, the other of said components consists of a copolyamide and further the core composed of said polyester component is embedded in said homopolyamide component without contacting with said copolyamide component.

11. The composite filament as claimed in claim 10, wherein the core and the copolyamide component of the sheath are arranged under such a condition that the lesser angle α formed by two straight lines, one of which connects the center of gravity of said core with the center of the filament and the other of which connects the center of gravity of said copolyamide component with the center of filament, in the cross section of the filament, is the range between 90° and 180°.

12. The composite filament as claimed in claim 10, wherein the shrinking percentage of the copolyamide component is at least 3 percent higher than that of the homopolyamide component.

13. The composite filament as claimed in claim 10, wherein said copolyamide consists of less than 95 percent by weight of a polyamide-forming constituent and more than 5 percent by weight of another polyamide-forming constituent.

14. The composite filament as claimed in claim 10, wherein said homopolyamide component is of nylon-6 or nylon-66.

15. The composite filament as claimed in claim 10, wherein said copolyamide component is of poly(caproamide/hexamethylene adipamide), poly(caproamide/hexamethylene isophthalamide) or poly(hexamethylene adipamide/hexamethylene sebacamide).

16. The composite filament as claimed in claim 10, wherein said homopolyamide and said copolyamide are arranged in a side-by-side relation.

17. The composite filament as claimed in claim 10, wherein said homopolyamide and said copolyamide are arranged in an eccentric sheath-core relation.

18. The composite filament of claim 1, wherein polyethylene terephthalate comprises at least 95 percent of said first component (a).

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