Nov. 10, 1964 W. H. JAMIESON 3,156,085

CONTINUOUS COMPOSITE POLYESTER FILAMENT YARN

Filed Sept. 24, 1959 3 Sheets-Sheet 1

FIG. 1

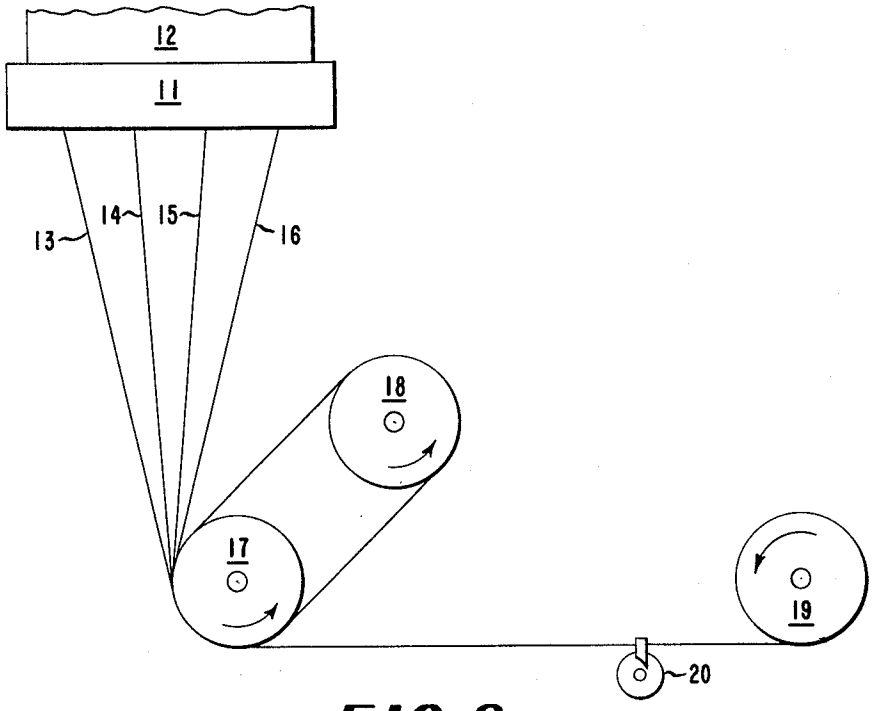
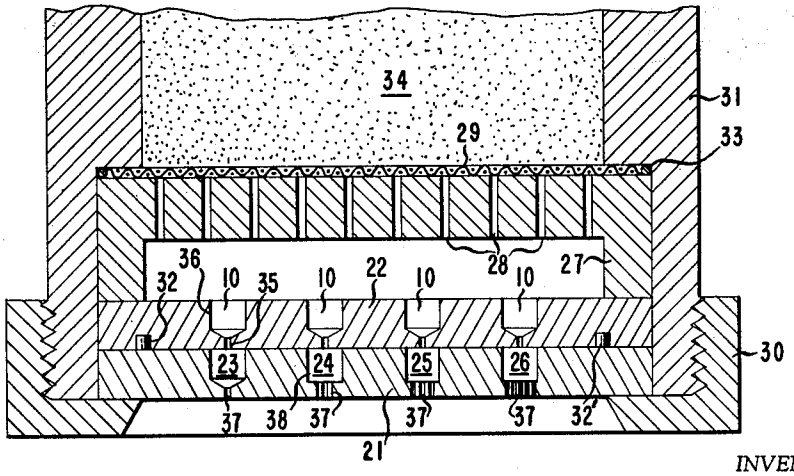


FIG. 2



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FIG. 3a

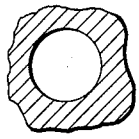


FIG. 3b



FIG. 4a

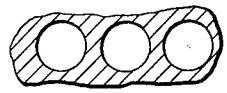


FIG. 4b



FIG. 5a

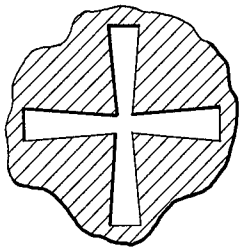


FIG. 5b

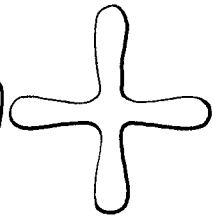


FIG. 6a

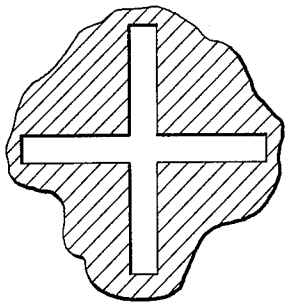


FIG. 6b

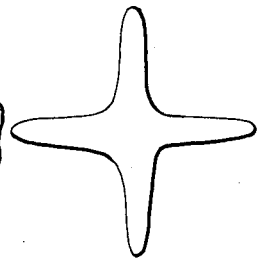


FIG. 7a

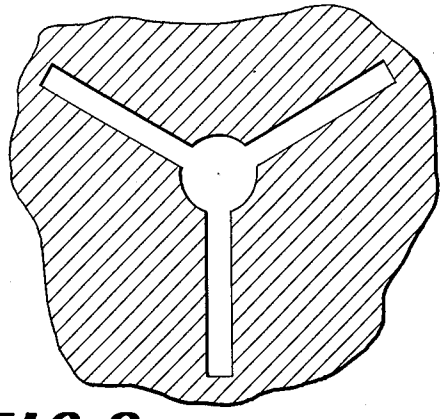


FIG. 7b

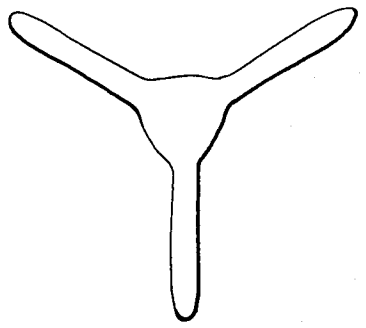


FIG. 8a

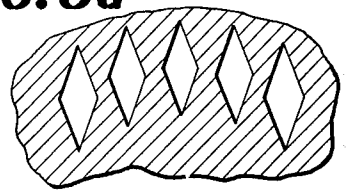
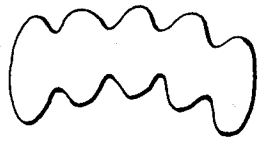


FIG. 8b



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FIG. 9a

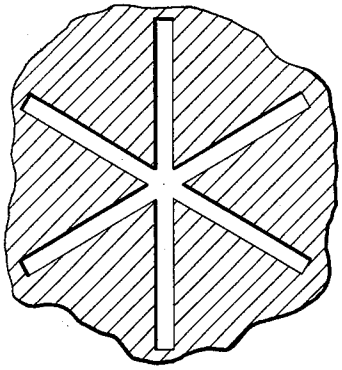


FIG. 9b

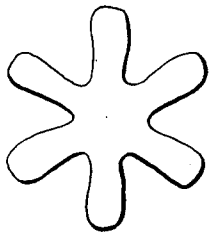


FIG. 10a

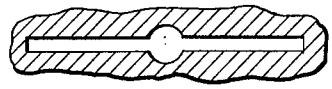


FIG. 10b



FIG. 11a

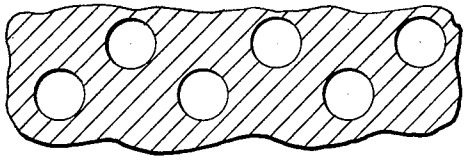


FIG. 11b



FIG. 12a

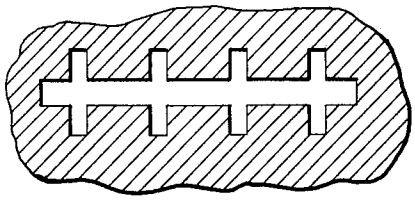


FIG. 12b



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United States Patent Office 3,156,085 Patented Nov. 10, 1964

3,156,085 CONTINUOUS COMPOSITE POLYESTER FILAMENT YARN

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Filed Sept. 24, 1959, Ser. No. 841,988
6 Claims. (Cl. 57—140)

This invention relates to composite polyester yarns and the process for manufacturing said yarns. More particularly, this invention relates to composite polyester yarns which have a highly uniform appearance in the form of dyed fabrics.

Synthetic linear condensation polyesters, and particularly the linear terephthalate polyesters, have attracted high commercial interest for many uses owing to their high tenacity, flexibility, crease resistance, low moisture absorption, and other valuable properties. Among such polyesters are polyethylene terephthalate and poly(p-hexahydroxylylene terephthalate). However, one difficulty has been associated with the polyesters in that the affinity of the polyester fibers for dyes changes markedly with variations in processing conditions. The sensitivity of the polyesters to varying conditions is such that even quite minor fluctuations in the process are sufficient to cause noticeable changes in the dye affinity of the fibers. In commercial production, it is frequently observed that non-uniformities occur sporadically within a single filament, or that one filament is continuously non-uniform wth respect to the average. These non-uniformities are observed as light or dark streaks in dyed fabrics and are regarded as highly objectionable.

Attempts have been made to solve the problem of non-uniformities in various ways. In general, attention has been focused on greater control of process variables such as polymer composition and molecuar weight, temperature during the spinning and orientation steps, and tension applied during the various steps. However, due to the inherent difficulty of the problem, these attempts have not met with complete success.

It is, therefore, an object of this invention to provide polyester yarns which have a uniform appearance in the form of dyed fabrics. Another object is to provide such yarns by a process which is less sensitive to small fluctuations in process conditions than processes used heretofore. Other objects of this invention will appear hereinafter.

Surprisingly, it has now been found that when filaments of different cross section are spun together and forwarded as a single filament bundle, the yarn so formed has a uniform appearance in the form of a dyed fabric. When the dyed yarn is observed under magnification, it is seen that the individual filaments have varied shades of color. However, as seen by the unaided eye, the overall appearance of the fabric is quite uniform. The yarn of which the fabric is made is also slightly more bulky than conventional continuous filament yarn of homogeneous cross section, and this also contributes to the desirable appearance of the fabric.

In carrying out the process of the invention, a molten linear condensation polyester is extruded through a plurality of spinneret orifices of different shapes. The polymer streams are then quenched and oriented, and the filaments so formed are forwarded as a single filament bundle to a collecting device. The filaments assume essentially the shape of the orifice through which they are extruded. The forwarding speeds may be selected within a wide range, forwarding speeds in excess of about 300 yards per minute usually being employed. It is generally desired that the extruded filaments be oriented to cause them to become tenacious. This may be done

simply by winding the extruded filaments at very high rates of speed, e.g., at about 3000 to 5200 yards per minute, as described by Hebeler in U.S. Patent 2,604,689. Alternatively, the extruded filaments may be wound up in a yarn bundle and then oriented by cold drawing the yarn up to about five times its original length in one or more separate steps as disclosed by Whinfield and Dickson in U.S. Patent 2,465,319. Because the orientation of the yarn in the spinning step increases with spinning speed, the draw ratio required to reach a given level of of orientation in the yarn decreases as the spinning speed increases.

In referring to the fiaments as having different cross sections, it is meant that the cross sections should differ markedly. A convenient numerical parameter relating to the shape of the cross sections is the "shape factor," which is defined by the equation

$$\text{Shape Factor} = P^2/A$$

where P is the perimeter of the cross section and A is its area, measured in the same units of length. Thus, a circle has a shape factor of 4 pi or 12.6; a square has a shape factor of 16; and a rectangle, having long sides four times the length of its short sides, has a shape factor of 25.

In accordance with the present invention, it has been found that at least one species of filaments in the filament bundle should have a shape factor of at least about 18. Thus, round filaments may be combined with filaments having ribbon-shaped (elongated rectangular), Y-shaped, or cruciform cross sections having shape factors of at least about 18.

In the event that all of the filaments in the bundle have the same number of well-defined "sides" in cross section, i.e., have the same general cross-sectional configuration, the shape factors of at least two species of filaments in the bundle should differ by a factor of at least 1.4. The term "sides" is intended to include curved surfaces. For instance, two varieties of cruciform filaments having shape factors differing by a factor of at least 1.4 may be combined in the same filament bundle; or two varieties of ribbon-shaped cross section filaments having shape factors differing by a factor of at least 1.4 may be used.

All of the cross sections may have essentially the same shape factor, provided that the shape factor is at least about 18 and the filaments differ markedly in cross-sectional shape. Preferably, in the latter case, at least two species of the filaments in the bundle should have cross sections having different numbers of well-defined sides. For example, Y-shaped cross section yarn may be used with a cruciform cross section yarn even though the two cross sections have the same shape factor. Similarly, a cruciform cross section filament and a ribbon-shaped cross section filament having the same shape factor may be used; or a cruciform cross section and a C-shaped cross section having the same shape factors may be used.

In accordance with the present invention, not more than about 75% of any one species of the filaments in the filament bundle should have the same shape factor and cross-sectional configuration.

In a preferred embodiment of the invention, three or more different cross sections are used. In one particularly desirable embodiment, not more than about 25% of each of several different species is utilized. Although each filament cross section need not be different, a variety of cross sections in the filament bundle is conducive to better uniformity. Since the cross sections of the filaments are governed by the shape of the orifices in the spinneret, a variety of filament cross sections can be obtained in each bundle simply by varying the orifice cross sections in the spinneret.

If desired, the filaments may be of different denier as well as of different cross section. However, it is preferred that the filaments be of substantially the same denier throughout the filament bundle. Through routine experimentation, the hole size for each orifice cross section appropriate for substantially equivalent polymer flow rates through the orifices may be determined. However, a simpler method of achieving this result is the use of a metering plate containing capillary holes aligned with the spinneret orifices. The diameter of the capillary holes in the metering plate are made sufficiently small with respect to the spinneret orifices that most of the pressure drop across the metering plate and the spinneret occurs within the metering plate. The denier of the filaments is thereby controlled primarily by the metering plate; and when substantially uniform deniers are desired, the diameters of the orifices in the metering plate are made uniform.

The invention will be further illustrated by reference to the accompanying drawings, in which:

FIGURE 1 is a schematic representation of suitable apparatus for spinning polyester filaments;

FIGURE 2 is a diagrammatic cross-sectional view of the portion of the spinnig head of FIGURE 1;

FIGURES *3a* through *12a* are bottom views of spinneret orifices of various cross-sectional configuration; and

FIGURES *3b* through *12b* are cross sections of filaments spun from the corresponding orifices of FIGURES *3a* through *12a*.

Referring now to FIGURE 1, the lower portion of a spinning head is represented by reference numeral **11**. Molten polymer metered to cavity **12** is extruded through orifices not illustrated forming filaments **13**, **14**, **15**, and **16**. The filaments are drawn away from the orifice by means of a pair of slightly axially skewed forwarding rolls **17** and **18**, and are delivered as a single yarn bundle to windup package **19**. The yarn is traversed onto package **19** by means of a reciprocating traverse guide **20**.

Referring to FIGURE 2, the spinning head includes a spinneret plate **21** positioned in contact with a metering plate **22**. Spinneret orifices **23**, **24**, **25**, and **26** are aligned with metering orifices **10**. A cupped distributor plate **27**, containing a plurality of holes **28**, is located upstream from metering plate **22**. The upstream face of distribution plate **27** is in contact with screen **29**. Retaining cap **30**, which is threaded onto spinneret housing **31**, secures the plates and screen in position. Pins **32** and **32'** on spinneret plate **21** are recessed into holes in the bottom of metering plate **22** and serve to align the orifices in the two plates. Gasket **33** provides a seal between screen **29**, cupped distribution plate **27**, and housing **31**. The cavity **34** in housing **31** is filled with a filtering medium such as sand.

Both the metering orifices **10** and spinning orifices **23**, **24**, **25**, and **26** have compound shapes. Orifices **10** consist of a capillary **35** and counterbore **36**. The spinneret orifices consist of jets **37** and counterbore **38**. The counterbores and capillaries are circular in cross section; however, the jets may have various shapes as illustrated in FIGURES *3a* through *12a*. The jets of spinneret orifices **23**, **24**, **25**, and **26** are shown in FIGURES *3a*, *6a*, *4a*, and *8a*, respectively. The counterbore cross-sectional areas are several times larger than the corresponding capillary and jet cross-sectional areas.

FIGURE *3a* illustrates a conventional orifice of round cross section, and FIGURE *3b* illustrates the conventional, round cross section of a filament spun from this orifice.

FIGURE *4a* illustrates a series of three round orifices spaced sufficiently closely that the polymer streams extruded from the orifices coalesce at the spinneret face. The holes are arranged in a straight line to afford a variegated ribbon-like cross-sectional pattern in the coalesced extruded filament, as shown in FIGURE *4b*.

FIGURE *5a* illustrates an orifice having the shape of a maltese cross. The cross section of the filament spun from the orifice is shown in FIGURE *5b*.

FIGURE *6a* illustrates an orifice of cruciform cross section, formed by the intersection of two punched slots. The cross section of the fiber spun from the orifice is shown in FIGURE *6b*.

FIGURE *7a* illustrates an orifice having the shape of a three-bladed propeller. The cross section of the filament spun from the orifice is shown in FIGURE *7b*.

FIGURE *8a* illustrates a series of five punched holes of diamond-shaped cross section spaced sufficiently closely that the polymer streams extruded from the orifices coalesce at the spinneret face. The holes are arranged in an arc to provide a variegated ribbon-like cross section in the coalesced extruded filament, as shown in FIGURE *8b*.

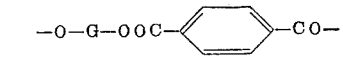
FIGURE *9a* illustrates an orifice having the shape of a six-legged star. The cross section of a filament spun from the orifice is shown in FIGURE *9b*.

FIGURE *10a* shows an orifice in the form of a two-bladed propeller. FIGURE *10b* illustrates the cross section of a filament spun from the orifice.

FIGURE *11a* illustrates an orifice having six round holes spaced in zigzag relationship which provides the filament of zigzag cross section shown in FIGURE *11b*.

FIGURE *12a* illustrates a four crosstie, ribbon-type orifice which provides a filament having a cross-section of the type shown in FIGURE *12b*.

In general, the variations in dye receptivity of filaments of different cross section is observed most significantly when the filaments are composed of a linear condensation polyester. Preferably, in accordance with the invention, a linear terephthalate polyester is employed. By "linear terephthalate polyester" is meant a linear polyester in which at least about 75% of the recurring structural units are units of the formula



wherein G represents a divalent organic radical containing from 2 to 12 carbon atoms and is attached to the adjacent oxygen atoms by saturated carbon atoms. Thus, the radical —G— may be of the form $—CH_2A_mCH_2—$, where *m* is 0 or 1 and A represents an alkylene radical, a cycloalkylene radical, a bis-alkylene ether radical, or other suitable organic radical. The linear terephthalate polyesters may be prepared by reacting terephthalic acid or an ester-forming derivative thereof with a glycol, $G(OH)_2$, where —G— is a radical as defined above, to form the bis-glycol ester of terephthalic acid, followed by polycondensation at elevated temperature and reduced pressure with elimination of excess glycol. Examples of suitable glycols include ethylene glycol, diethylene glycol, butylene glycol, decamethylene glycol, and cis- or trans-bis-1,4-(hydroxymethyl) cyclohexane. Mixtures of such glycols may suitably be used to form copolyesters, or small amounts, e.g., up to about 15 mol percent, of a higher glycol may be used, such as a polyethylene glycol. Similarly, copolyesters may be formed by replacing up to about 25 mol percent of the terephthalic acid or derivative thereof with another dicarboxylic acid or ester-forming derivative thereof, such as adipic acid, dimethyl sebacate, isophthalic acid, or sodium 3,5-dicarbomethoxybenzenesulfonate.

Surprisingly, the novel yarns of the invention not only have a more uniform appearance than conventional yarns of homogeneous cross section but in fabric form they are also somewhat more bulky and have a more pleasing "hand." This results in part from a differential response to heat treatment exhibited by linear terephthalate polyester filaments of various cross sections, in which the changes in length of the various filaments when heated differ by amounts ranging up to several percent. After the filaments are heated, the longer filaments are disposed

outwardly from the shorter filaments in the form of loops protruding from the axis of the yarn bundle. The greater bulk of the yarn bundle also results in part from the fact that filaments of different cross section generally do not pack together in the yarn bundle as closely as filaments of homogeneous cross section.

The following examples will serve to further illustrate the invention and are not intended to be construed as limitative.

Example I

A 5-inch stainless steel spinneret plate is prepared containing ten different orifice cross sections. Each of the orifices is provided with a 1/16 inch diameter counterbore section. The spinneret contains a total of 34 orifices, seven round orifices and three of each of the orifices having the configurations illustrated in FIGURES 4*a* through 12*a*.

Polyethylene terephthalate having an intrinsic viscosity of 0.53 and containing 0.3% TiO_2 is spun at 296° C. from the orifices described above, using a metering plate having 9-mil capillary sections above the spinneret plate. The filaments extruded from the spinneret are collected as a single filament bundle. The filament bundle is wound up at a speed of 1200 yards per minute and it is found to have an as-spun denier of 240. The spun yarn is oriented by passing it from a feed roll maintained at 96° C. and operating at a peripheral speed of 150 yards per minute, thence to an unheated draw roll operated at a peripheral speed of 454 yards per minute, after which the yarns are wound on a conventional windup. The drawn yarns are found to have a denier of 96.8, a tenacity of 2.5 grams per denier, and an elongation of 30.3%.

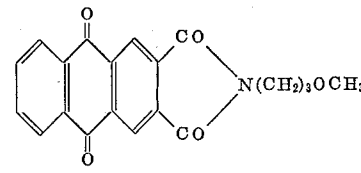
The drawn yarns are woven into a taffeta fabric containing 90 ends per inch in the warp and 76 ends per inch in the filling. The fabric is dyed for four hours at 100° C. in a dye bath comprising 2% of 1,4-diamino-2,3-dichloroanthraquinone, based on the weight of the fabric. A control fabric is prepared as just described except round filaments are utilized in lieu of the filaments of different cross-sectional shapes. The dyed fabric is observed to be more uniform in appearance than the control fabric prepared from the conventional, round cross section polyethylene terephthalate yarn. The fabric prepared from the yarn containing filaments of different cross section is also observed to be somewhat more attractive in appearance and to have a somewhat softer hand than the control fabric.

Example II

A 3-inch stainless steel spinneret is fabricated containing forty-four 1/16 inch diameter counterbores. From 22 of the counterbores 15-mil diameter round holes are drilled, while from the other 22 counterbores cruciform orifices are prepared by punching two intersecting 4 x 34 mil slots from each counterbore section. Polyethylene terephthalate having an intrinsic viscosity of 0.53 and containing 0.2% TiO_2 is spun at 295° C. from the spinneret, the filaments being wound up together as a single bundle at 1200 yards per minute. The yarn is oriented as described in the preceding example. The drawn yarn is found to have a denier of 61.0, a tenacity of 4.3 grams per denier, an elongation of 13.6%, and an initial modulus of 114 grams per denier. Individual round and cruciform filaments are teased out from the filament bundle and it is found that the round filaments have an average vibrational denier of 1.59 and an average shrinkage in 100° C. water of 9.8%, while the cruciform filaments are found to have an average vibrational denier of 1.55 and an average shrinkage of 9.12%.

The yarn is woven into a taffeta fabric containing 90 ends per inch in the warp and 76 ends per inch in the filling. The fabric is dyed for four hours at 100° C. in

a dye bath comprising 2% (based on the fabric weight) of a dye having the formula



The dyed fabric is observed to be more uniform in appearance than a control fabric prepared from conventional round cross section polyethylene terephthalate yarn prepared under the same conditions.

In addition to the procedures just described, the products of this invention may also be prepared by combining filaments from different spinnerets. They may be used in continuous filament or staple yarn form.

The novel yarns of this invention may be advantageously used in a variety of fabric constructions. They may be dyed either prior to or after being knitted or woven into a fabric. They may be dyed usink known dyes for polyester yarns.

As many widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that this invention is not to be limited to the specific embodiments thereof except as defined in the appended claims.

I claim:

1. Linear polyester yarn having a uniform appearance in the form of dyed fabrics comprising a plurality of continuous filamentary structures having a uniform cross section along their length, said yarn consisting of at least two species of filamentary structures having different cross-sectional shapes, the cross section of one of said species having a shape factor of at least about 18, not more than about 75% of any one of said species being present in said yarn, with the proviso that when the cross sections of said species have essentially the same number of sides the shape factor of one of said species be at least 1.4 times greater than that of the other species.

2. The yarn of claim 1 wherein said polyester is polyethylene terephthalate.

3. The yarn of claim 1 wherein the major portion of said filaments are round.

4. The yarn of claim 1 wherein at least three species of filaments are present in said yarn.

5. The yarn of claim 1 wherein all of said filaments have essentially the same denier.

6. A dyed fabric having a uniform appearance prepared from linear polyester yarn comprised of a plurality of continuous filamentary structures having a uniform cross section along their length, said yarn consisting of at least two species of filamentary structures having different cross-sectional shapes, the cross section of one of said species having a shape factor of at least about 18, not more than about 75% of any one of said species being present in said yarn, with the proviso that when the cross sections of said species have essentialy the same number of sides the shape factor of one of said species be at least 1.4 times greater than that of the other species.

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