

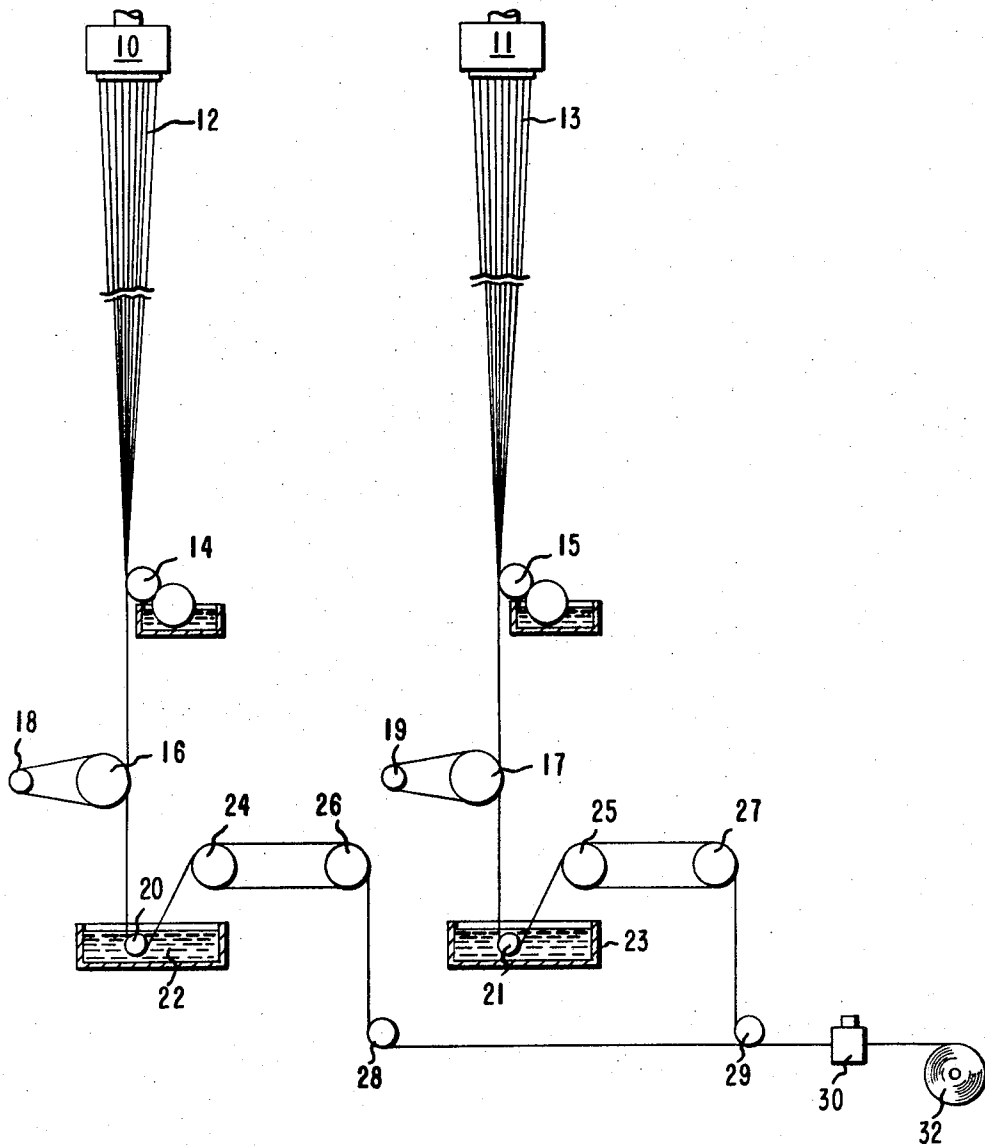
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R. E. TAYLOR

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PROCESS FOR PREPARING SILK-LIKE POLYESTER YARN

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INVENTOR
ROBERT EDWARD TAYLOR

BY *Norris E. Ruckman*
ATTORNEY

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PROCESS FOR PREPARING SILK-LIKE POLYESTER YARN

Robert Edward Taylor, Camden, S.C., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del.
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3 Claims

ABSTRACT OF THE DISCLOSURE

A silk-like appearance is provided in fabric by polyester yarn prepared by melt-spinning bright polymer containing surface-modifying agent through non-round spinneret orifices to produce rough-surfaced filaments of different cross-sections, and drawing the filaments to 0.75–1.5 denier with a part being subjected to conditions different from other filaments to impart differential shrinkability. Alternatively a different polymer composition is used in part of the filaments to impart differential shrinkability.

REFERENCE TO RELATED APPLICATIONS

This is a division of my copending application Ser. No. 871,418, now U. S. Pat. No. 3,608,296, filed Oct. 28, 1969, as a continuation-in-part of copending application Ser. No. 564,905 filed July 13, 1966 (abandoned).

This invention relates to a process for melt-spinning and drawing synthetic linear polyester into textile yarn. More particularly, it relates to production of yarn for weaving into fabrics having essentially the aesthetic appeal of natural silk.

In the history of the textile industry the place of silk is unique. The fine, strong, lustrous fibers recovered from the cocoons of the larvae of the *Bombyx mori* were long ago found to give luxurious fabrics with an aesthetic appeal unmatched by other fibers. Because of its limited supply and highly desirable attributes, silk became a royal fiber—a fiber of kings and queens and persons of high rank. Even today the price of raw silk is twenty times that of raw cotton.

With the advent of man-made synthetic fibers and the ability to tailor fiber properties to suit different end uses, it is understandable that a continuing search has gone on for a synthetic fiber with all of the desirable properties of silk. Many attempts have been partially successful in approaching the properties of silk, but prior to the present invention no one had succeeded in matching the warm, deep luster, the liveliness and attractive luxurious handle of real silk.

The present invention provides a synthetic polyester yarn for preparing silk-like fabrics which are indistinguishable in appearance from natural silk fabrics, even to a trained observer. The invention provides a process for manufacturing the yarn from low-cost polymer by practical and economical processes easily adapted to large-scale commercial production. Thus, for the first time, the textile industry is freed from centuries of dependence upon the silkworm and the tedious methods used to produce natural silk.

In accordance with the present invention, there is provided a silk-like, synthetic linear condensation polyester multifilament yarn characterized by a novel and critical combination of physical features. As disclosed in detail below, the yarn is composed of at least two filament species exhibiting differential shrinkability of at least 1.7% as defined below and consists essentially of non-

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round cross-section filaments averaging 0.75 to 1.5 denier per filament with an average shape factor greater than 13, and are preferably of a variety of cross-sections. The filaments are composed of "bright" polymer, i.e., with a TiO_2 content no greater than 0.1% and free from other delusterants; the filaments possess a rough surface indirectly characterized by a coefficient of dynamic friction of less than about 0.70 in the "flooded" test and less than about 0.45 in the "film" test; the total yarn denier is between about 15 and about 100 (1.7 tex to 11 tex). Preferably the yarn contains a mixture of filament deniers. Non-round cross-sections which are primarily trilobal in character are preferable.

The result achieved by combining the above features is especially surprising because when they are taken separately, or in more simple combinations, they do not give silk-like yarns. When all of the conditions specified above are met, the yarns form fabrics which are amazingly silk-like in general appearance, luster, tactility, and resilience. Furthermore, in addition to the aesthetic appeal of silk, fabrics prepared from the yarns of this invention possess all of the well-known ease-of-care properties offered by the new synthetic polyester fibers.

The above silk-like yarn is produced by a process of melt-spinning and drawing synthetic linear polyester into yarn wherein a "bright" polyester is prepared containing at most 0.1 per cent TiO_2 and free from other delusterants, a finely-divided inert surface roughening agent is incorporated in the polyester, the polyester is melt spun through non-round spinneret orifices into filaments of different cross-sections and the filaments are forwarded through a drawing operation to produce filaments averaging 0.75 to 1.50 denier per filament. Differential shrinkability of at least 1.7 percent is imparted by subjecting a part of the filaments to temperatures different from another part in the course of their production. Filament bundles may be forwarded through separate drawing operations under different conditions and then be combined into a yarn by interlacing, twisting or plying. Alternatively, differential shrinkability may be obtained by plying or cospinning filaments from two different polymers. Preferably filaments are combined to form a yarn of 15 to 100 denier.

In the drawing, which illustrates apparatus for carrying out the process,

The single figure is a schematic showing of an embodiment of the process and equipment for spinning and drawing the filaments to make the yarn.

Referring to the drawing, molten polymer is spun through two side-by-side spinnerets 10 and 11. The filament bundles 12 and 13 are cooled, wetted with spin finish by rolls 14 and 15, and gathered separately at feed rolls 16 and 17. The filament bundle 12 passes around feed roll 16 and its guide roll 18 is fed to draw pin 20 immersed in hot aqueous bath 22, and is drawn by a pair of draw rolls 24 and 26. The drawn filaments then pass over a guide roll 28, through an interlacer 30 and to the wind-up 32. The other filament bundle 13 is similarly handled by feed roll 17 and its guide roll 19, draw pin 21 in bath 23, draw rolls 25 and 27, and guide roll 29. The two filament bundles are combined at interlacer 30.

As indicated above, the yarns of the present invention must be composed of differentially shrinkable components, one component species having a higher residual shrinkage than a second species and the two species differing by a ΔS value of at least 1.7 percentage points. The parameter ΔS is the difference between the "boil-off" shrinkage of the higher shrinkage species, measured under a restraining tension of 0.02 gram per denier and expressed as percent of the original sample length, and the dry heat shrinkage of the lower shrinkage species, measured at 160° C.

with no restraining tension and similarly expressed as percent of original sample length. Yarns so characterized, after being woven into fabric, boiled off or scoured, and then ironed or heat-set, yield bulky fabrics with a soft, supple hand.

By "residual shrinkage" as used herein is meant the capability remaining or existing in the filament or yarn for linear contraction under the specified tension in water at 100° C. or when exposed to 160° C. dry heat for an exposure time of 5 minutes. When the tension is not specified, residual shrinkage under zero tension is implied. The term "shrinkability" is also used synonymously with "residual shrinkage" as an attribute of a filament or yarn. When used alone, the term "shrinkage" refer to the actual step of carrying out linear contraction of a filament or yarn, or the observation of the amount of linear contraction. Filaments or yarns which exhibit no change in length when heated are regarded herein as the limiting case in which the shrinkage is zero (0.0%). In some cases, the filaments or yarns may be stretched when they are heated while held under tension; in such cases, the length change is regarded as shrinkage of negative value.

For the purpose of the invention, satisfactory determinations of boil-off shrinkage values are made as follows: To measure shrinkage of the yarn under a load of 0.02 g.p.d., the denier of the yarn sample is determined and an 8 to 15 centimeter sample is prepared and measured to the nearest 0.01 centimeter. The weights are then clamped to the yarn and adjusted to provide a total load on the yarn of 0.02 g.p.d., when corrected for the buoyancy of water, and the sample is placed in water at 100° C. for 2 to 5 minutes, making sure that the sample and weight hang free in the water and are completely covered by the water. The final length of the sample is measured before removing it from the water and the percentage shrinkage is calculated in accordance with the formula:

$$\text{Shrinkage} = \frac{(\text{Original Length} - \text{Final Length}) \times 100\%}{\text{Original Length}}$$

The yarns of this invention consist essentially of non-round cross-section filaments with an average shape factor greater than 13. Non-round filaments are necessary. If all of the other parameters described previously are properly adjusted with the exception of cross-section, and if round filaments predominate, the fabrics prepared from the yarn exhibit a smooth, waxy hand which is easily distinguished from silk.

Shape factor is defined by the equation:

$$\text{Shape factor} = \frac{P^2}{A}$$

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 4π or 12.6, while a square has a shape factor of 16.)

It will be recognized that, in a multifilament yarn bundle, the effect of a small percentage of round filaments is masked by a preponderance of non-round filaments; and consequently, the presence of a few round filaments will not destroy the silk-like character of fabrics produced from the yarn. The allowable percentage of round filaments in the yarn of the invention may be as high as about 25% of the total number of filaments, but it is preferred that at least 90% of the filaments have non-round cross-sections.

In a preferred embodiment of the invention, more than one type of filament cross-section is present in a given yarn. That is to say, the yarn is composed of a plurality of groups of non-round filaments with each group having a cross-section different from that of the other groups.

The yarns of this invention must be prepared from bright polymer, i.e., non-delustered polymer. It has become customary in the synthetic fiber business to incorporate in the polymer before spinning a white pigment having a high refractive index, such as TiO_2 . TiO_2 con-

centrations of 0.3% and 2% by weight are common. The presence of TiO_2 in filaments causes internal scattering of light and thereby imparts a certain amount of opacity to the filaments. In the present invention, on the other hand, opacity of filaments is to be avoided. The filaments must be composed of polymer containing either no TiO_2 , or in any case, no more than about 0.1% by weight. More than this amount destroys the silk-like luster of the filaments. Other delusterants, such as BaSO_4 or void spaces, should be absent. Also, the filaments are preferably solid, not hollow.

The filaments making up the yarns of this invention must possess a certain amount of surface roughness to prevent them from being "shiny." The subtle lustre of silk is destroyed by the presence of shiny filaments. Surface roughness is most conveniently measured by its effect on the coefficient of hydrodynamic friction. The filaments making up the yarns of this invention have coefficients of hydrodynamic friction, f_k , less than about 0.70 measured on a "flooded" chrome pin, or less than about 0.45 on a "wiped" chrome pin, in the test described below.

In a preferred embodiment of the invention, filament surface roughness is obtained by incorporating in the polymer, before spinning, a finely-divided inert material having a refractive index close to that of the polymer. Those materials are satisfactory which have a refractive index within about 0.15 refractive index units of the polymer. Such materials impart surface roughness without causing internal scattering of light. A preferred material for use in polyethylene terephthalate is purified kaolinite having a particle size in the 0.5–5 micron range. Other surface-roughening agents include calcium terephthalate, potassium acetate, potassium terephthalate and potassium 3,5-di(carbomethoxy)benzenesulfonate.

As indicated previously, the novel yarns of this invention are composed of filaments having a denier per filament in the range 0.75 to 1.5 (0.08 tex to 0.17 tex). Filaments of this size are required to obtain the desired properties. If the average denier per filament is below 0.75 (0.08 tex), fabrics produced from the yarns are dead and mushy. Alternatively, if the average denier per filament is above 1.5 (0.17 tex), fabrics produced from the yarns are stiff and harsh. The soft, luxurious handle of natural silk is only obtained when the denier per filament is between 0.75 and 1.5. Preferably the yarn is composed of filaments of varied denier within this range.

The preferred yarns of the present invention are those having a yarn denier less than about 100. This limitation on total yarn denier is an artificial limitation imposed by the historical fact that natural silk fabrics have generally been prepared from light-denier yarns. Larger bundles of filaments having the characteristics specified herein would, of course, still exhibit silk-like luster and tactility.

One of the problems in developing a synthetic yarn which matches the appearance of natural silk has been the lack of an objective test for yarn luster. Thus, the evaluation of new yarns has depended upon the subjective opinions of trained observers. This situation is partially alleviated by the following test for over-all yarn luster. The sample yarn is wound at a tension of 0.5 g.p.d. on a black card in a single yarn layer with adjacent yarn bundles touching, but not overlapping. This sample is compared with a similar test card (control) prepared from a color-sealed black (carbon-black filled) polyethylene terephthalate filament yarn composed of round-cross-section filaments. The test card is illuminated with a constant intensity, collimated light beam aimed perpendicular to the length dimension of the yarn and making an angle of 10 degrees with the plane occupied by the parallel rows of yarn. The intensity of scattered light is then measured with a suitable light meter at angles of 60° and 155° between the incident light beam and the reflected beam, the vertex of the angle being the illuminated yarn. A suitable light meter, used herein, is a "Densichron" optical density meter (W. M. Welch Scientific Co., Chicago, Ill.)

equipped with a blue-sensitive sensing element and a scale reading in "optical density units" ranging from 1.5 (black) to zero (illuminated white). ("Luster units" are obtained by multiplying optical density units by a factor of 100.) The difference in readings between test yarns and black yarns at the two angles has been found to be significant. The novel yarns of the present invention exhibit a reflectance difference of less than about 60 luster units (0.60 optical density units) at an angle of 60°, and a reflectance difference greater than about 120 luster units (1.20 optical density units) at an angle of 155°. Yarns having a reflectance difference greater than 60 at an angle of 60° are found to give fabrics which are too delustered or flat to be considered silk-like. Yarns containing less than 0.1% TiO₂ and having a reflectance difference less than 120 at an angle of 155° give fabrics which are too shiny.

The term "synthetic linear condensation polyester," as used herein, comprehends a substantially linear polymer of fiber-forming molecular weight comprising a series of predominantly carbon-atom chains joined by a recurring carbonyloxy radical,



As used herein, the term "polyester" is intended to include copolyesters, terpolyesters, and the like. Included, for example, are the polyesters disclosed in U.S. Patents Nos. 2,465,319, 2,901,466 and 3,018,272. Polyesters having an intrinsic viscosity of at least about 0.3 are considered to be of fiber-forming molecular weight. Intrinsic viscosity has been defined in U.S. Pat. No. 3,057,827. The term RV used in the examples refers to Relative Viscosity at a nominal concentration of 10%. RV is measured as described in U.S. Pat. No. 3,216,187, Column 3, line 56.

Dibasic acids useful in the preparation of polyesters and copolyesters of this invention include terephthalic acid, isophthalic acid, sebacic acid, bibenzoic acid, hexahydro-terephthalic acid, ethylenedibenzoic acid, isopropylidenebenzoic acid, 4,4'-dicarboxydiphenyl ether, 4,4'-dicarboxy-m-terphenyl, 2,6- and 2,7-naphthalenedicarboxylic acid. Glycols useful in the preparation of the polyesters and copolyesters of this invention include the polymethylene glycols such as ethylene glycol, trimethylene glycol and tetramethylene glycol and branched-chain glycols such as 2,2-dimethyl-1,3-propanediol and 2,2-dimethyl-1,4-butanediol. Also included are

cis- and trans-hexahydro-p-xylene glycol, bis-p-(2-hydroxyethyl)-benzene, diethylene glycol, bis-p-(beta-hydroxyethoxy)benzene, bis-4,4'-(beta-hydroxyethoxy)diphenyl, 1,4-dihydroxy[2·2·]bicyclooctane, 2,2-bis(4-hydroxyphenyl)propane, 4,4'-dihydroxybiphenyl, (bicyclohexyl)-4,4'-dimethanol, 1,2-bis(4-hydroxymethylcyclohexyl)ethane, 2,2-bis(4-hydroxymethylcyclohexyl)propane, and 1,4-bis(hydroxymethyl)bicyclo[2·2·2]octane.

Other polyester-forming reagents include bifunctional compounds such as beta-hydroxy-pivalic acid, hydroxyacetic acid, and the like.

The coefficient of hydrodynamic friction, f_k , is measured by hanging a test filament over a 1/2-inch diameter (12.7 mm. diameter) polished chrome-plated mandrel so that the filament contacts the mandrel over an arc of approximately 180°. A 0.3-gram weight is attached to one end of the filament (input tension) and a strain gauge is attached to the other end (output tension). The mandrel is rotated at a speed of 1800 r.p.m. and the area of contact "flooded" with a drop of No. 50 mineral oil im-

mediately before the strain gauge readings are made for the data marked "flooded." For data marked "film," the oil is wiped from the mandrel with only a thin film remaining. The coefficient, f_k , is calculated from the belt equation:

$$f_k = \frac{1}{a} \ln \left(\frac{T_2}{T_1} \right)$$

where f_k is the coefficient of hydrodynamic friction, $\ln$ is the natural logarithm ($\log_e$), T_1 is the input tension, T_2 is the output tension, and a is the angle of wrap in radians.

The following examples will serve to illustrate the invention further, although they are not intended to be limitative. Unless otherwise indicated, all parts and percentage figures are by weight.

Example I

A copolyester of polyethylene terephthalate containing 2 mol percent 5-sodiumsulfoisophthalate radicals is prepared according to the general procedure of U.S. Pat. No. 3,018,272, and during polymerization a sufficient quantity of glycol slurry of finely-divided calcium terephthalate is added to give a concentration of 1.4% calcium terephthalate in the final polymer. The mixture is polymerized to an intrinsic viscosity of about 0.52, extruded as a ribbon, quenched, cut to flake, and stored for further use.

The polymer prepared above is remelted in a screw extruder and melt-spun at a temperature of 297° C. through two side-by-side 25-hole spinnerets, each having five groups of five non-round holes, and each group being slightly different from the other four. The hole shapes correspond generally to the printed characters L, V, Y, I, and Δ. Each spinneret assembly is also fitted with a distribution plate of the general type described by Cobb in U.S. Pat. No. 3,095,607. The plates have five groups of five metering holes each, with each group having a slightly different size from the other four groups, and are so arranged that the bundle of 50 extruded filaments is composed of 25 pairs of nearly identical filaments, each pair being different from the others.

The extruded filaments are quenched in air, wetted with a conventional spin finish and passed around a feed roll operating at a surface speed of 1280 y.p.m. (1165 m.p.m.). The filaments are then passed around a draw pin immersed in an aqueous finish draw-bath maintained at a temperature of 90° C., and split into two separate bundles (25 filaments each) for drawing and heat treating. One bundle is passed to and around a pair of draw rolls heated to 105° C. and rotating at a surface speed of 2750 y.p.m. (2510 m.p.m.). The other filament bundle is passed around a second pair of draw rolls operating at 169° C. and rotating at 2750 y.p.m. (2510 m.p.m.). The filament bundles proceeding from the two sets of draw rolls are then recombined, interlaced as described in Bunting et al. U.S. Pat. No. 3,110,151, and wound up as a 70-denier yarn having a break elongation of about 25%. The average denier per filament is found to be 1.4 (0.16 tex).

The filaments drawn with the 105° C. draw rolls are found to have a residual shrinkage at 0.02 g.p.d. load of about 9% in 100° C. water. The filaments drawn with the 169° C. draw rolls are found to have a residual shrinkage of 4.3% at 160° C., giving a ΔS of 4.7%.

The filaments of the yarn produced are all found to have a non-round cross-section with no filament having a shape factor less than 13.2, and with the average shape factor for all filaments being about 15.1. The denier spread among the filaments is by a factor of about 4/1 from the largest to the smallest.

When the yarn is wound on a mirror card and tested for an angular light reflectance in the luster test described previously, the reflectance difference at an angle of 60°

is found to be 64 and the reflectance difference at an angle of 155° is found to be 160.

Friction measurements give a coefficient of friction, f_k , of 0.36, measured on a "flooded" chrome pin.

The yarn produced above is woven into a plain weave taffeta fabric and subjected to a subjective evaluation by a panel of trained observers. There is general agreement that the luster, luster highlights, tactility and resilience of the fabric are amazingly like those of natural silk.

Example II

A copolyester of polyethylene terephthalate containing 2 mol percent 5-sodiumsulfoisophthalate radicals is prepared according to the general procedure of U.S. Pat. No. 3,018,272. The procedure is modified by the addition to the initial ingredients of 0.85% potassium acetate, based on final weight of polymer. The presence of potassium acetate in polyesters is found to result in filaments having a roughened surface. Polymerization is continued until a relative viscosity of 18.8 (intrinsic viscosity about 0.5) is attained, and then the polymer is extruded as a ribbon, quenched, cut to flake and stored for further use.

The polymer prepared above is remelted in a screw extruder and melt-spun at 299°C . using a single spinneret assembly of the type described in Example I. The 25 extruded filaments are quenched in air, wetted with a conventional spinning finish, passed around a feed roll operating at a surface speed of 860 y.p.m. (786 m.p.m.), then around a draw pin immersed in an aqueous finish bath maintained at a temperature of 90°C ., then around a pair of draw rolls (13 wraps) heated to 107°C . and rotating at a surface speed of 2750 y.p.m. (2510 m.p.m.). The yarn is wound up as a 35-denier, 25-filament yarn having a break elongation of 27%.

Half of the above-prepared yarn is then heat-set at constant length by passing it over a pair of rolls heated to 200°C . without stretching or without allowing the yarn to undergo shrinkage. This heat-set yarn is then combined with the remainder of the yarn, which has not been heat-set, interlaced as in U.S. Pat. No. 3,110,151, and wound up as a 70-denier 50-filament yarn. The average denier per filament is found to be 1.4 (0.16 tex).

Those filaments heat-set on the 200°C . rolls are found to have a residual shrinkage of about 3.6% at 160°C . Those filaments which did not receive the 200°C . heat treatment are found to have a residual shrinkage at 0.02 g.p.d.-load of 11.0% in 100°C . water. The ΔS value, therefore, is 7.4%.

The filaments of the yarn produced are all found to have a non-round cross-section with no filament having a shape factor less than 13.3, and with the average shape factor for all filaments being about 15.2. The denier spread among the filaments is by a factor of 2/1 for the greatest to the smallest.

In the general yarn luster test the yarn is wound up on a mirror card and tested for angular light reflectance as described previously. The reflectance difference at an angle of 60° is found to be 50, and the reflectance difference at an angle of 155° is found to be 147.

Friction measurements give a coefficient of friction, f_k , of 0.49, measured on a "flooded" chrome pin.

As in Example I, the yarn produced above is woven into a plain weave taffeta fabric and subjected to a subjective evaluation by a panel of trained observers. The general conclusion of the panel is that the luster, luster highlights, tactility, and resilience of the fabric are closer to that of natural silk than any fabric encountered prior to the present invention.

Example III

This example illustrates the preparation of a yarn similar in most respects to the yarn of Example II but which is not silk-like because of an excessive concentration of TiO_2 .

A copolyester of polyethylene terephthalate containing 2 mol percent 5-sodiumsulfoisophthalate radicals and having dispersed therein 2 weight percent TiO_2 is melt-spun in the manner of Example II using the spinneret assembly described in that example. The extruded filaments are quenched in air, wetted with a conventional spin finish, passed around a feed roll operating at 1700 y.p.m. (1550 m.p.m.), around a draw pin immersed in an aqueous finish bath maintained at 90°C ., then around a pair of draw rolls heated to 110°C . and rotating at 2750 y.p.m. (2510 m.p.m.) are then wound up as a 35-denier (3.9 tex) yarn. Half of the yarn produced is heat-set at constant length by passing it over a pair of rolls heated to 200°C . This heat-treated yarn is combined with the remainder of the original drawn yarn to give a differentially shrinkable, 70-denier, 50-filament yarn which is then interlaced as in U.S. Pat. No. 3,110,151 and wound into a package. The average denier per filament is found to be 1.4 (0.16 tex).

Those filaments heat-set on the 160°C . rolls are found to have an average zero-load residual shrinkage of 4.2% at 160°C . Those filaments which did not receive the 160°C . heat-treatment are found to have a residual shrinkage at 0.02 g.p.d.-load of about 11.8% in 100°C . water. The ΔS value is 7.6%.

The filaments of the yarn are all non-round in cross-section and no filament has a shape factor less than 13.2. The average shape factor for all filaments is about 15.1. The denier spread is by a factor of about 4/1 from the largest to the smallest.

In the general yarn luster test, the yarn is wound on a mirror card and tested for angular light reflectance as described previously. The reflectance difference at an angle of 60° is 76, and the reflectance difference at an angle of 155° is 100.

Friction measurements give a coefficient of friction, f_k , of 0.58, measured on a "flooded" pin.

The yarn produced above is woven into a plain weave taffeta fabric and examined by a panel of trained observers. All observers agree that the fabric has a chalky appearance and does not exhibit luster or the luster highlights characteristic of natural silk.

Example IV

This example illustrates the preferred range of the differential shrinkage function of ΔS for a silk-like balance of resilience and softness.

A series of yarns is prepared according to a general procedure equivalent in major aspects to that described in Example I. The supply polymer is a copolymer of polyethylene terephthalate containing 2 mol percent sodium 5-sulfoisophthalate for dyeability, and further modified by the incorporation of 0.8% by weight of potassium acetate to provide surface roughness in the filaments produced. The spun yarn bundle is split downstream from the draw bath as described in Example I, and one portion passed over draw rolls heated at 185°C . while the other portion is passed over another set of draw rolls heated at a lower temperature, as shown in Table 1. The separately heated portions are then recombined to provide a yarn having the value of ΔS shown in the table. Item 5 is a control yarn spun from the same polymer, but the yarn bundle is not split after it leaves the draw bath and therefore exhibits no differential shrinkage. Each yarn is woven into a plain weave taffeta fabric and evaluated subjectively by a panel of trained observers. While all fabrics have the luster, luster highlights and tactility of silk, there is general preference for the fabrics woven from the yarns having a ΔS value greater than 1.7% but less than 9.0%. The fabric having a ΔS value of 9.0% was found to be too soft, while the fabric from yarn having a ΔS value of 1.7% has been found to be less resilient than the best samples although still more silk-like than the control sample which had no differential shrinkage.

Item	Draw roll temp., °C.	TABLE 1			Fabric bulk	
		f_k	ΔS , percent	Cc./g.	Rating	
		Film				
1-----	80	0.33	0.58	9.0	2.8	Soft.
2-----	85	0.36	0.57	6.3	2.5	Best.
3-----	90	0.34	0.56	3.8	2.4	Do.
4-----	100	0.34	0.57	1.7	2.2	Good; less resilient.
5-----		0.33	0.59	0	1.7	Slick, non-bulky.

Fabric bulk (cc./g.) is calculated from fabric weight per unit area and fabric thickness. Fabric thickness is determined by ASTM test method D-1777 using an ultra-sensitive gauge (supplied by The Sheffield Corporation, Dayton, Ohio), a circular presser foot having a 3-inch diameter, a loading pressure of 3 gm./cm.², and a loading time of 30 seconds.

Example V

This example illustrates the effect of surface roughness on silk-like luster and luster highlights of polyester yarns.

A series of yarns are spun in a manner similar to that described in Example I except that the polymer used contains different concentrations of kaolinite (instead of calcium terephthalate) to provide different levels of surface roughening in the filaments produced. The yarns are

bright polymer containing finely-divided aluminum silicate as a surface roughener. One yarn consists of filaments having a variety of cross-sections as described in Example I, while the other consists of filaments all having the same trilobal cross-section with a modification ratio of 2.1. Properties are shown in Table 3. Plain weave taffeta fabrics are prepared from these two yarns, finished to substantially the same bulk factor, and evaluated by a panel of trained observers. The fabric prepared from the mixed-cross-section yarn possesses the visual appearance, luster and luster highlights of silk whereas the fabric from yarn of uniform filament cross-section, even though trilobal, does not show the luster highlights of silk, although admittedly more silk-like than an equivalent fabric from round cross-section filaments.

TABLE 3

Code	Cross section	Yarn, denier/No. filaments	Aluminum silicate conc., percent	Fabric bulk		
				ΔS	Cc./g.	Rating
Via-----	Trilobal-----	70/50	2.1	5.5	2.94	Duller and drier hand than V1b.
V1b-----	Mixed, silk-like---	70/50	1.8	7.5	2.99	Silk-like luster and silk-like hand.

all composed of filaments having a uniform trilobal cross-section with a modification ratio of 2.1. "Modification ratio," as applied to a filament cross-section, is the ratio of the radius of a circumscribed circle to that of an inscribed circle (U.S. Pat. No. 2,939,201, column 3, line 24). Each yarn is woven into a plain weave taffeta fabric for testing, with the properties shown in Table 2. The fabrics, when examined by a panel of trained observers, are found to have the most silk-like luster and luster highlights in fabrics coded C, D and E in the table. In contrast, fabrics A and B, characterized by "film" f_k values above 0.45, are found to be too shiny, as well as lacking sufficient "cover."

TABLE 2

Item	Count, den./fil.	Kaolinite, percent	f_k , film	Fabric bulk		
				ΔS	Cc./g.	Luster
A-----	70/50	0	0.50	5.2	-----	Shiny.
B-----	70/50	1.0	0.48	3.1	2.17	Do.
C-----	70/50	2.1	N.A.	5.5	2.94	Silk-like.
D-----	70/52	2.3	0.41	4.0	2.82	Do.
E-----	70/50	2.9	0.27	5.9	2.52	Do.

¹ Estimated.

Example VII

This example illustrates the effect of differential shrinkage on silk-like character.

A polyethylene terephthalate yarn composed of filaments with mixed cross-sections and mixed shrinkages is prepared according to the general procedure of Example I from polymer containing finely-divided aluminum silicate to provide surface roughness. For comparison, a control yarn is prepared in the same manner with the exception that the yarn bundle is not split for heat-treating after drawing, i.e., all filaments are processed in the same manner and have the same shrinkage characteristics ($\Delta S=0$). Plain weave taffeta fabrics are prepared from both yarns and finished by similar procedures. The fabric from yarn possessing a differential shrinkage is much livelier and softer and has the attractive drape of silk. The fabric from yarn having no differential shrinkage, although showing the luster and luster highlights of a silk-like yarn, is found to be hard and deficient in liveliness as well as showing a less attractive drape. Properties are shown in the following table:

TABLE 4

Aluminum silicate conc., percent	f_k , film	Yarn, denier/No. filaments	ΔS	Fabric		
				Weight, oz./yd. ²	Bulk, cc./gm.	Rating
2.1-----	0.27	70/50	4.5	2.0	2.35	Lively, soft.
2.5-----	0.31	70/50	0	2.2	1.70	Relatively stiff, low liveliness.

Example VI

This example illustrates the improved silk-like character obtained by using a yarn composed of filaments having a variety of cross-sections when compared directly with a yarn composed of filaments having the same cross-section.

Two polyethylene terephthalate yarns are prepared according to the general procedure of Example I from

Example VIII

This example illustrates an alternative method of obtaining differential shrinkage between filament groups, and a preferred filament cross-section for silk-like character.

Using a spinning machine which allows the melt spinning of two different polymers through separate groups of holes in the same spinneret, polyethylene terephthalate

homopolymer having an RV of 31 is cospun with a 38 RV copolyester of ethylene glycol and a mixture of terephthalic and isophthalic acids (93/7 mol ratio). Both polymers are free of TiO_2 , and both contain 2% by weight of finely-divided kaolinite to provide surface roughness. The spinning temperature is 306°C . The geometry of the capillaries of the 50-hole spinneret is such that each quenched filament has a trilobal cross section roughly similar to that shown in FIG. 2 of U.S. Patent No. 3,216,186 issued to Opfell on November 9, 1965. After converging the filaments into a single thread-line and drawing them in a 96°C . aqueous draw bath, using a draw roll temperature of $127\text{--}130^\circ\text{C}$., the 67 denier yarn is wound into a package. The yarn produced is found to have a tenacity of about 3.6 g.p.d., a break elongation of about 33%, an initial modulus of about 88 g.p.d., and to consist of two distinct groups of filaments differing in shrinkage. The higher shrinkage filaments have a boil-off shrinkage of about 12% and the lower shrinkage filaments have a boil-off shrinkage less than 8%, giving a differential shrinkage greater than 4%. Close examination of the filament cross sections reveals uniform trilobal filaments with a shape factor well above 13 and, using the nomenclature of the above-mentioned Opfell patent, a line of symmetry with an included angle α of 140° between pendant lobes, and a ratio, r/AB , of radius of curvature of pendant lobes to the distance between centers of the center lobe and a pendant lobe equal to 0.618.

The above yarn is then woven into a plain weave fabric with the warp yarn portion being duntwisted 3 turns Z and then uptwisted $4\frac{1}{2}$ Z and twist set before weaving, and the filling yarn duntwisted to 3 turns Z only. After scouring and heat setting at 170° , the fabric has an end count of 106 per inch and a pick count of 84 per inch. Subjective evaluation by trained observers results in the conclusion that the fabric is remarkably silk-like in luster and in tactile aesthetics.

Example IX

This example illustrates the preparation of a silk-like fabric from a yarn containing a minor proportion of round filaments mixed with a major proportion of trilobal filaments.

Two polyesters, polyethylene terephthalate homopolyester having an RV of about 30 and polyethylene terephthalate/isophthalate (83/7 mol. ratio) copolyester having an RV of about 34, each free of TiO_2 but containing 2 weight percent of finely divided kaolinite particles, are separately prepared and fed simultaneously to a melt-spinning machine. The two polyesters are cospun through a 300°C ., 50-hole spinneret with the homopolymer being extruded through 25 Y-shaped holes and the copolyester being extruded through 15 Y-shaped holes and 10 round holes. The extruded filaments are quenched in cross-flow air, passed around rotating feed rolls, then through an aqueous draw bath maintained at 93°C ., and then around draw rolls rotating at 2554 yards per minute to produce a draw ratio of about 4.1. The drawn yarns are lightly intermingled and wound up as a zero-twist 70 denier yarn composed of 40 filaments having a trilobal cross section and 10 filaments having a round cross-section. The average denier per filament is 1.4. Examination of the cross sections of trilobal filaments reveals an average shape factor of about 15.4–15.9.

Examination of the drawn yarns in a shrinkage test shows that the yarn is composed of two different shrinkage species having a difference in shrinkage of about

5%. The higher shrinkage filaments are those composed of the copolyester.

Friction measurements give a coefficient of friction, f_k , of 0.51–0.54, measured on a "flooded" chrome pin, and a value of 0.33–0.32 measured on a "wiped" chrome pin.

The yarn produced above is woven into a plain weave taffeta fabric. The yarn used for the warp is duntwisted 3 turns Z, uptwisted $4\frac{1}{2}$ Z additional twist, twist set, single-end sized and warped. Yarns used for the filling is duntwisted 3 turns Z and used without further treatment. The greige fabric has an end and pick count of 104 by 76. The fabric is scoured at the boil for 30 minutes, rinsed in water and air dried, and then heat set on a pin frame at 160°C . for 5 minutes. The finished fabric has an end count of 120 and a pick count of 85 per inch, a weight of 1.93 oz./yd.², and a measured bulk of 2.51 cc./g. under a loading pressure of 3 gm./cm.². In a subjective evaluation by a panel of trained observers, the fabric is found, by general agreement, to show the luster, luster highlights, tactility, and resilience of a fabric composed of natural silk filaments. The fabric is easily distinguished from, and much superior to, a comparison fabric prepared from yarns similar in all respects to the above yarn with the exception that all filaments have a round cross section.

I claim:

1. In the melt-spinning and drawing of synthetic linear polyester into yarn, the process of producing yarn for weaving into silk-like fabric which comprises preparing a "bright" polyester containing at most 0.1 percent TiO_2 and free from other delusterants, incorporating in the polyester a finely divided inert material having a refractive index close to that of the polyester to impart surface roughness characterized by a coefficient of friction of less than 0.70 in the flooded test and less than 0.45 in the film test of filaments produced, melt-spinning the polyester through non-round spinneret orifices into filaments of different non-round cross-sections and forwarding the filaments through a drawing operation to produce filaments averaging 0.75 to 1.50 denier per filament with an average shape factor greater than 13, a part of the filaments being subjected to temperatures different from another part to impart a differential shrinkability of at least 1.7 percent, and combining the filaments into a yarn.

2. The process defined in claim 1 wherein the filaments are combined to form a yarn of about 15 to 100 total denier.

3. The process defined in claim 1 wherein the finely divided inert material incorporated in the polyester is purified kaolinite having a particle size in the 0.5–5 micron range.

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