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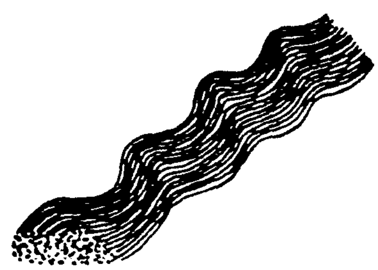
(54) Readily processable cotton-like terephthalate polyester staple.

(57) There is described a mass of convoluted terephthalate polyester staple fiber which contains fiber bundles that have a corrugated crimp pattern. The mass of staple fibers is processable at high speeds either alone or blended with other staple fibers to yield yarns from which polyester fabric having a cotton-like feel may be produced.



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Readily Processable Cotton-like Terephthalate Polyester Staple

This invention relates to a staple fiber mass of convoluted crimped terephthalate polyester fiber that may be made into an all-polyester fabric having the look and feel of natural cotton fabric. The staple fiber mass can be processed on conventional textile equipment at commercial speeds into spun yarns. The spun yarn made of the convoluted crimped terephthalate polyester fibers alone or blended, as the cotton-like component with conventional polyester fiber, yields fabrics combining cotton-like aesthetics with the durability, dimensional stability, and ease-of-care characteristics of polyester fabrics.

It is known in the art to produce terephthalate polyester fiber of nonround cross section having a convoluted structure which imparts high bulk to yarns composed of such fibers, and which is particularly adapted to obtaining voluminous strands of continuous filaments with bulkiness properties similar to those yarns obtained from natural staple fibers. Such fiber is produced by extruding a molten synthetic linear polyester through a spinneret orifice to form a filament having at least one fin extending from a stem portion, quenching the filament by directing a controlled flow of quenching gas across it near the orifice, and forwarding the filament through the quenching zone at a high rate of speed. The quenched filament is drawn from 1 to 4 times its original length under amorphous retaining conditions, i.e., under conditions which induce a minimum of crystallinity, and the drawn filament is shrunk 15-75% resulting in a convoluted filamentary structure. Such known filaments comprise a stem and at least one fin having a width at least 1.4 times its thickness, the fin or fins of which are convoluted (in the form of a ruffle or helix around the stem), there being from several to several hundred convolutions per centimeter. The filaments have a denier preferably in the range of 1 to 10. Such filaments are disclosed in U.S. Patent 3,219,739 to Breen et al.

According to one aspect of the present invention their is thus provided a mass of terephthalate polyester staple fiber, said staple fiber having a crystallinity index greater than about 10, a linear density of 1 to 6 decitex, a tenacity greater than 1 decinewton per tex, and a cross sectional shape when cut perpendicular to the longitudinal dimension of the fiber comprising a stem portion and at least one fin portion, said at least one fin portion having a width at least 1.4 times its thickness, said at least one fin portion being convoluted around said stem portion to the extent of about 5 to 300 convolutions per centimeter of length, a portion of said staple fiber being present in the form of fiber bundles, said fiber bundles having a corrugated crimp pattern, a bundle crimp frequency of 2 to 12 crimps per centimeter of length and bundle crimp index of 5 to 40%, said fiber bundles being present in said mass to the extent of at least 1000 fiber bundles per kilogram of said mass.

According to a further aspect of the present invention there is provided a blend of the mass of terephthalate polyester staple fiber of the invention with other staple fibers, such as for example cotton or crimped terephthalate polyester fibers, said blend containing at least 100 fiber bundles per kilogram, said bundles containing convoluted fibers and having a corrugated crimp pattern.

The convoluted terephthalate polyester staple fiber is a convoluted fiber of the type broadly described in the Breen et al. patent but has specific properties only generally disclosed in the Breen et al. patent. It has a linear density of 1 to 6 decitex, a tenacity greater than 1 decinewton per tex, and a crystallinity index greater than about 10.

The convoluted terephthalate polyester staple fiber is particularly characterized in that fiber bundles of convoluted fiber present in the mass of fiber have a corrugated crimp pattern, a bundle crimp frequency of 2 to 12 crimps per centimeter of length, and a bundle crimp index of 5 to 40.

According to a yet further aspect of the invention there is provided a method of the preparation of the mass of terephthalate polyester staple fiber of the invention which method comprises drawing crimping and subsequently cutting a tow of terephthalate polyester filaments the transverse cross-sectional shape of which filaments comprises a stem portion and at least one elongate fin portion extending therefrom.

According to a still further aspect of the invention there is provided a yarn spun from the mass of terephthalate polyester staple fiber of the invention or the blend of the invention.

The preparation and characteristics of embodiments of the invention will now be discussed by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a representation of a spinneret orifice suitable for use in the production of the convoluted terephthalate polyester staple fiber mass of this invention;

FIGS. 2-6 are schematic representations of some of the various cross-sectional shapes of terephthalate polyester fibers suitable for incorporation in the staple fiber mass of this invention;

FIG. 7 is a representation in lateral view and greatly enlarged, of a convoluted fiber of a type suitable for making up the staple fiber mass of the invention; and

FIG. 8 is a representation, greatly enlarged, of a staple fiber bundle of the type found in the staple fiber mass of the invention.

The term "convolution", as used herein, comprehends not only ruffles but also reversing helical turns of the fins about the fiber stem. The terephthalate polyester staple fibers have either ruffles or helical convolutions or both. In an idealized convolution, a plane can be drawn through the fiber axis such that the fins project first from one side of the plane and then from the other, so that in a complete cycle of a convolution a fin passes through the plane twice.

The expression "convolutions per centimeter", as used herein, represents the number of times that the fin passes through the plane twice, whether in the form of ruffles or helices, per cm. of length of the fiber. In measuring the number of convolutions per cm., a representative sample of staple fibers is obtained and twelve convoluted fibers are selected at random from the sample. The selected fibers may contain segments which are unconvoluted so long as a portion of the fiber is convoluted; however, any fibers which are not convoluted at all when observed under a microscope are rejected. The twelve fibers are taped on glass slides, four on a slide parallel to one another and under enough tension to keep the fibers straight, but not enough to pull out convolutions. A cover slide marked with lines 1 cm. apart is placed upon the slide above the taped fibers. The fibers are observed in an optical microscope at 100X magnification. A count is then made of the number of definite identations along one side only of each fiber, between lines spaced at 1-cm. intervals, each indentation corresponding to a fin crossing the center line of the fiber or reaching a minimum distance from the center line of the fiber. FIG. 7 illustrates the indentations 1 which are counted along convoluted fiber 2 having ruffles 3 and helices 4 and 4' of opposite pitch meeting at reversal 5. For each fiber a count is made along at least two adjacent 1-cm. segments, so that a total of at least 24 segments is counted. The average number of convolutions per centimeter for the sample is calculated by totaling the number of definite indentations counted for all segments, dividing by the number of segments which were counted, and then dividing again by the number of fins in the fiber cross section (since a complete cycle of a helical convolution requires one indentation on the same side of the fiber for each fin in the fiber cross section, and the measure of convolutions employed herein is based upon the count of indentations). The lowest and highest values for individual 1-cm. segments are reported separately as the range of convolutions per cm.

The term "fin" means an elongated portion of a nonround fiber cross section. A fin may be straight, bent, or curved. The cross section may have a single fin or more than one fin.

The term "stem" of the fiber means the root or body of the fiber from which the fins protrude. Generally the stem is the area at which two or more fins intersect. The propeller cross section (FIGS. 4 and 6) is defined herein as two fins protruding essentially in opposite directions from a stem. The keyhole cross section (FIG. 2) is a special case in which a single fin protrudes from a stem located at one end of the fin. A ribbon cross section (FIG. 3) is another special case in which the fiber has two fins which meet at the center of the fiber cross section and the stem is regarded as the median portion of the ribbon cross section--see Ex. II of Breen et al. U.S. 3,219,739. The cross section may have more than one stem, e.g., a cross section in the shape of an "H".

The term "width" (W) of the fin means the length of a line (termed "width line") extending from the tip of the fin to the center of the stem. The width line is drawn within the periphery of the fin, equidistant from the sides of the fin, from the tip of the fin to the point where the fin joins the stem, the line then being extended to the center of the stem. In the case of the ribbon cross section, the center of the stem is the midpoint between the two tips. In the case of the keyhole and propeller cross sections, the center of the stem is taken as the center of the largest circle which can be inscribed within the periphery of the cross section.

The term "thickness" (T) of the fin means the average distance across the fin periphery as measured perpendicular to said width line. The fin width-to-thickness ratio, W/T, has a value of at least 1.4. This ratio is determined by embedding in a clear resin numerous fibers or filaments having their fiber axes substantially aligned, sectioning the embedded fibers perpendicular to their axes, and preparing a 600X optical photomicrograph of the sectioned fibers. A group of 12 representative and substantially adjacent cross sections is selected in the photomicrograph; and for each of the 12 cross sections W and T are measured and the ratio W/T determined. The twelve W/T ratios are averaged.

The term "fiber bundle" means a plurality of closely packed longitudinally aligned staple fibers that coheres together. The fibers of a fiber bundle are often of the same approximate length, and often the ends are in the same plane. A fiber bundle varies in length from about 1 to 20 centimeters. Fiber bundles are formed when multifilament tow is severed to form fibers of staple length. Bulk quantities of staple fibers made by conventional textile methods contain many such fiber bundles, which usually contain at least 20 fibers and more typically contain about 100 to 200 fibers or more.

The term "crimp" means a series of pronounced regular changes in the direction of the axis of a fiber (each pronounced change in direction is called a "bend"). A single crimp is made up of two successive bends.

Fiber bundles, especially those contained in the fiber mass of the present invention, may exhibit "bundle crimp". Bundle crimp means that each of the fibers of the fiber bundle is substantially aligned with one another so that the crimp pattern usually crosses the entire bundle. The bundle thus displays a corrugated crimp pattern, with the bends in the fibers forming ridges which alternate in up-down or side-to-side sequences. Adjacent ridges in the corrugated pattern are not always precisely parallel to one another. FIG. 8 is a drawing of a typical fiber bundle which has a corrugated crimp pattern.

The average number of crimps per centimeter in a fiber bundle is determined as the "bundle crimp frequency" by the following method. From a sample of the staple fibers to be measured, three typical fiber bundles having a corrugated crimp pattern are removed at random. The mass of staple fibers of the invention contains at least 1000 of these fiber bundles per kilogram of mass. The fiber bundles removed are trimmed by stripping out fibers only loosely associated with the bundle, e.g., with tweezers. Partially associated fibers which might disrupt the structure of the bundle if stripped out completely are clipped off flush with the bundle to complete the trimming of the bundle. One end of the trimmed fiber bundle is clamped with a first clamp, very close to the end of the bundle. A small clamp weighing about 0.3g is then clamped very close to the other end of the bundle (for fiber bundles containing less than about 100 fibers, a clamp weighing proportionately less than 0.3g is used). The fiber bundle is then suspended substantially vertically by the first clamp against a finely graduated ruler, with the bundle being tensioned only by the weight of the small clamp, and the distance between the clamps is measured in centimeters, to a precision of 0.05

cm. or better and recorded as R. The total number of ridges on one side of the fiber bundle only is then counted and recorded as the number of crimps, N, between the clamps. The fiber bundle is then gently straightened by pulling down on the small clamp, taking care not to pull out the fibers beyond their straightened length; and the distance between the clamps is measured in centimeters, to a precision of 0.05 cm. or better, and recorded as S. To determine the bundle crimp frequency, data from three bundles are required. The bundle crimp frequency in crimps per centimeter is calculated for each fiber bundle by dividing N by S, and the results for the three fiber bundles are averaged. The "bundle crimp index", a measure of the quality of the crimp, is calculated from the data obtained from the same fiber bundles, using the following formula:

$$\text{Bundle Crimp Index, \%} = \frac{(S - R) \times 100}{S}$$

The calculated values for bundle crimp index for the three fiber bundles are then averaged.

The bundle crimp frequency and bundle crimp index are determined in essentially the same manner for blends of the fiber mass of this invention and other staple fibers, except that the bundles must be examined to determine that they contain convoluted fibers. In such a blend the number of crimped convoluted fiber bundles will be at least 100 per kilogram.

The term "crystallinity index" is an empirical value calculated from an intensity ratio obtained from an X-ray reflection diffractometer scan and is a measure of the degree of crystallinity of a polyester, although it should not be interpreted as percent crystallinity. To determine the crystallinity index, fibers are positioned parallel to one another across the top of a flat sample holder and an X-ray diffraction pattern substantially parallel to the axes of the fibers is recorded from 10° to 36° (2θ), using a standard reflection diffractometer equipped with a theta-compensating slit and a crystal monochromator. For polyethylene terephthalate the greatest intensity of the amorphous halo occurs around 20° (2θ) and is located in the valley between two crystalline diffraction peaks, one of which is at approximately 17.6° (2θ). The crystallinity index is the ratio of the intensity difference between the amorphous halo and crystalline peak to the intensity of the crystalline peak alone and is determined by drawing a background baseline on the diffraction pattern from approximately 11° to 31°, recording the intensity of the peak at approximately 17.6° as A in chart divisions, recording the intensity of the background baseline as B in chart divisions, recording the intensity of the amorphous halo (minimum intensity at about 20°) as C in chart divisions, and calculating the result from the following formula:

$$\text{Crystallinity Index} = \frac{(A - C) \times 100}{A - B}$$

The crimped, convoluted terephthalate polyester fiber has a crystallinity index of at least 10. At this level of crystallinity and above the fiber has adequate stability.

The relative viscosity of the polyester, designated in the examples as "HRV" (acronym for Hexafluoroisopropanol Relative Viscosity) is determined as described by Lee in U.S. Patent No. 4,059,949, Column 5, line 65 to Column 6, line 6. The polyester should have an HRV of about 10 to 40, preferably 15 to 25.

Conventional physical test methods are employed for determination of linear density, tenacity (t), elongation, and tenacity at 7% elongation (t_7) of the staple terephthalate polyester fibers. Similarly, conventional methods are used for determining the spun yarn linear density, and its boil-off shrinkage, Lea Product, and skein breaking tenacity.

Lea Product and skein breaking tenacity are measures of the average strength of a textile yarn and are determined in accordance with ASTM procedure D1578 (Published 1979) using standard 80-turn skeins.

The term "terephthalate polyester" includes not only polyethylene terephthalate, but polyesters of terephthalic acid with other glycols such as cyclohexane dimethanol, and fiber-forming copolyesters thereof wherein a portion of the terephthalic acid is replaced by another organic acid or a portion of the glycol is replaced by another organic hydroxyl-containing compound. Inert materials may be incorporated into the polyester composition.

The term "mass" means quantity of fibers of no particular size or shape. A mass of fibers may exist as a pile, stack, in a container, or in a bale. A mass of fibers may be loosely associated or tightly compressed. A mass of fibers may contain individual fibers that are more or less randomly oriented, and will also contain bundles of fibers that are aligned together.

The staple fibers in the mass of the present invention generally have a length in the range of about 1 to 20 centimeters and preferably about 2 to 15 centimeters.

The number of fiber bundles per kilogram of mass of terephthalate polyester staple fiber can be determined by weighing out a sample of staple fiber (usually at least several grams) then counting the number of fiber bundles in the sample. If the weight of the sample employed is not a kilogram, then the appropriate mathematical calculations are made to give the result in bundles per kilogram.

The staple fiber mass of the present invention is primarily used to make spun yarns. It is in this use that the fiber mass of this invention have a clear advantage over the fibers of Breen et al. U. S. Patent 3,219,739. The staple fibers in the staple fiber mass of the present invention can be processed to staple yarns at commercial speeds on currently available textile equipment with no significant adjustments required; whereas convoluted fibers of the same size and tenacity made by following the prior art disclosures could be processed only at low, commercially unacceptable speeds.

When used alone, the convoluted terephthalate polyester staple fibers can surprisingly be formed by commercial methods into spun yarns and then into fabrics which have truly cotton-like visual and tactile aesthetics. Yet, these fabrics are superior to cotton fabrics in that they have the desirable characteristics associated with all-polyester fabrics--wrinkle resistance, dimensional stability, durability, and wash-wear launderability.

The fiber mass of the present invention may be blended with other fibers, either synthetic or natural, e.g., cotton, and when made into fabrics give products having properties intermediate to those of the components. The fiber blend may contain up to 90% by weight conventional unconvoluted crimped polyester staple fibers having 2 to 12 crimps per centimeter. Such a fiber mass may be processed into spun yarns and then into fabrics which have polyester/cotton visual and tactile aesthetics, the convoluted fibers simulating the cotton fibers in the blend. The all-polyester fabrics are more durable and have greater dimensional stability in washing than the corresponding polyester/cotton fabrics. Moreover, the all-polyester fabrics are highly wrinkle-resistant; so that there is no need to treat the fabrics with resin to improve the wrinkle resistance, as is frequently done with polyester/cotton fabrics.

An additional advantage of blends of the fiber mass of the invention and conventional polyester staple fiber, is that such a blend can be processed into spun yarns and fabrics more simply than cotton fibers or blends containing cotton, since the steps of combing, bleaching, and mercerizing are eliminated.

If desired, the fiber mass of the invention can be provided with a permanent hydrophilic coating to enhance its cotton-like character.

The following Examples are provided to illustrate the preparation and properties of masses of terephthalate polyester staple fibers according to the invention.

EXAMPLE 1

Poly(ethylene terephthalate) containing 0.1 wt. % TiO_2 and having a HRV of about 22 was extruded at the rate of 10.2 kg/hr. from a spinneret having 300 propeller-shaped orifices, like that shown in FIG. 1, each orifice consisting of a slot measuring 0.076 mm (3 mils) in width X 1.78 mm (70 mils) in length enlarged at its mid-point with a round hole 0.23 mm (9 mils) in diameter, with the center of the round hole coinciding with the geometrical center of the slot. The spinneret pack temperature was 304-305°C and the extruded filaments were quenched with air at room temperature at the rate of 3.0 m^3/min., a portion of the air being directed radially inward below the periphery of the spinneret through a cylindrical screen 15.2 cm. high having an area of 0.071 m^2 and the remainder as a cross-flow through a flat screen 20.3 cm. wide having an area of 0.129 m^2. The extruded filaments were gathered into a 300-filament yarn and wound up at speed of 3000 m/min.

Ninety-six ends of the 300-filament yarn were combined to form a tow. The tow was drawn on a spray-draw machine of the type generally disclosed by Paulsen in his U.S. Patent 2,918,346 by passing it at a speed of 47.5 m/min. (52 ypm) from the feed roll section through an aqueous spray at a temperature of 60°C to a draw roll section, the draw ratio being 1.6X.

Added to the aqueous spray, in the form of an aqueous emulsion, was a finish composition comprising about 40 parts by weight cocotrimethyl-ammonium methosulfate, 25 parts coconut oil, 20 parts sorbitolpolyoxyethylene(30) tetraoleate/laurate, 5 parts disodium N-lauryl-β-iminodipropionate, 0.3 part KOH, and 9 parts polyoxyethylene(5) hydrogenated tallowamide, the concentration of the finish composition being adjusted to provide a finish level of 0.36 wt. % on the staple fiber product. The drawn tow was fed through a stuffer box crimper at room temperature (no external heating), after which the crimped tow was continuously piddled onto a moving belt and passed through a relaxer oven wherein it was subjected to a temperature of 135°C for a residence time of ten minutes. The tow was then cut to a mass of staple fibers having a cut length of 3.8 cm. (1.5 in.) and a linear density of 2.0 dtex per filament (1.8 dpf). The staple fiber product had a typical fiber cross section (magnified) in the form of a propeller, or stem portion with two opposed fin portions, as shown in FIG. 4. The width of the fin portion measured 3.9 times its thickness. Examination of the staple fibers revealed that they were convoluted and contained crimp. Numerous fiber bundles comprised of convoluted fibers and having a corrugated crimp pattern were observed within the mass of staple fibers. The bundle crimp frequency was determined to be 4.1 crimps per cm. (10.4 crimps per inch) and the bundle crimp index was determined to be 16.2%. The mass of staple fibers contained more than 1000 fiber bundles per kilogram. Additional fiber properties are listed in Table I.

Staple fibers prepared as described above were processed on the cotton system from a picker lap through a conventional flat card system at the rate of 9.3 kg/hr. The resulting sliver was processed through a draw frame (2 passes), a roving frame, and a ring-spinning frame. Two spun yarns were prepared, one having a linear density of 227 dtex (26 cotton count) and designated as Yarn 1A, and the other having a linear density of 148 dtex (40 cotton count) and designated as Yarn 1B. The properties of these yarns are listed in Table II.

Yarn 1A was knitted on a circular knitting machine to form a 22-cut single knit plain jersey fabric. The fabric had a pleasing cotton-like hand.

EXAMPLE 2

Poly(ethylene terephthalate) containing 0.1 wt. % TiO_2 and having an HRV of about 23 was extruded from a spinneret having 900 propeller-shaped orifices, each orifice consisting of a slot measuring 0.089 mm (3.5 mils) in width x 1.50 mm (59 mils) in length enlarged at its mid-point with a round hole 0.23 cm. (9 mils) in diameter, with the center of the round hole coinciding with the geometrical center of the slot. The spinneret pack temperature was 288°C and the extruded filaments were quenched with air at room temperature at the rate of 5.4 m^3/min. through the quenching apparatus described in Example 1. The extruded filaments were gathered into a yarn and wound up at a speed of 1830 m/min. The 900 as-spun filaments had a linear density of 3.17 dtex per filament (2.86 dpf).

Fifty ends of the 900-filament yarn were combined to form a tow of about 14,200 tex (128,300 denier). The tow was drawn on a spray-draw machine by passing it from the feed roll section through an aqueous spray at a temperature of 68°C to a draw roll section, the draw ratio being 1.88X and the final speed of the tow being about 116 mpm (127 ypm). Added to the aqueous spray, in the form of an aqueous emulsion, was the finish composition described in Example 1 at a concentration adjusted to provide a finish level of 0.45 wt. % on the staple fiber product. The drawn tow was fed through a stuffer box crimper at room temperature, after which the crimped tow was continuously piddled onto a moving belt and passed through a relaxer oven wherein it was subjected to a temperature of 135°C for a residence time of ten minutes. The tow was then cut to a mass of staple fibers having a cut length of 3.18 cm. (1.25 in.). The staple fiber product had a propeller fiber cross section in which the width of the fin portion measured 3.7 times its thickness. Examination of the staple fibers revealed that they were convoluted and contained crimp. Numerous fiber bundles of convoluted fibers and having a corrugated crimp pattern were observed within the mass of staple fibers. The bundle crimp frequency was determined to be 4.0 crimps per cm. (10.2 crimps per inch) and the bundle crimp index was determined to be 17.6%. The mass of staple fibers contained more than 1000 fiber bundles per kilogram. Other fiber properties are listed in Table I.

Staple fibers prepared as described above were processed on the cotton system sequentially through a chute-fed, conventional flat card system (at the rate of 22.7 kg/hr.), a draw frame (2 passes), a roving frame, and a ring-spinning frame. The properties of the spun yarn so prepared, designated as Yarn 2, are listed in Table II.

Yarn 2 was knitted on a circular knitting machine to form a 22-cut single knit plain jersey fabric. The fabric had a pleasing cotton-like hand indistinguishable from an authentic cotton fabric of the same construction.

EXAMPLE 3

Poly(ethylene terephthalate) containing 0.3 wt. % TiO_2 and having an HRV of about 23 was extruded from a spinneret having 34 propeller-shaped orifices of the same dimensions as the orifices of the spinneret of Example 1. The spinneret pack temperature was between about 290 and 293°C and the extruded filaments were quenched with a cross flow of room temperature air at the rate of about 4.67 cubic meters per minute (165 cubic feet per minute) through a flat screen 152 cm. high having an area of 0.35 m^2. The extruded filaments were gathered into a yarn and wound up at a speed of 2800 m/min. The as-spun yarn contained 34 filaments and had a linear density of 84 dtex (2.47 dtex per filament).

Sixteen ends of the 84 dtex yarn were combined to form a yarn of approximately 1350 dtex, and thirteen ends of the 1350 dtex yarn were then further combined to form a tow of approximately 17,500 dtex containing 208 ends. The tow was drawn on a tow drawing machine by passing it from the feed roll section through an aqueous bath maintained at a temperature of 63°C to a draw roll section, the draw ratio being 1.55X and the final speed of the tow being about 38 mpm (42 ypm). Added to the aqueous bath was a finish composition essentially comprising a 15% by weight aqueous solution of (1) about 67 parts by weight of a major amount of polyethylene glycol (400) monolaurate and a minor amount of polyethylene glycol (400) lauric amide and (2) about 33 parts by weight of the diethanolamine salt of mono- and di-alkylphosphates, the concentration of the finish composition being adjusted to provide a finish level of 0.10 wt. % on the staple fiber product. The draw tow was fed through a stuffer box crimper at room temperature, after which the crimped tow was continuously piddled onto a moving belt and passed through a relaxer oven wherein it was subjected to a temperature of 170°C for a residence time of ten minutes. The tow was then cut to a mass of staple fibers having a cut length of 3.8 cm. (1.5 in.). Examination of the staple fibers revealed that they were convoluted and contained crimp. Numerous fiber bundles comprised of convoluted fibers and having a corrugated crimp pattern were observed within the mass of staple fibers. The bundle crimp frequency was determined to be 4.1 crimps per cm. (10.4 crimps per inch) and the bundle crimp index was determined to be 12.9%. The mass of staple fibers contained more than 1000 fiber bundles per kilogram. Other fiber properties are listed in Table I.

(A) Spun yarn prepared from 100% crimped, convoluted staple fibers. Staple fibers prepared as described above were processed on the cotton system sequentially through a chute-fed card, a draw frame (2 passes), a roving frame, and a ring-spinning frame. The properties of the spun yarn so prepared, designated as Yarn 3A, are listed in Table II.

(B) Spun yarn prepared from a blend of crimped, convoluted staple fibers with conventional polyester staple fibers. Staple fibers prepared as described in the first two paragraphs of this example were processed through a chute-fed card and through the first pass of a draw frame as in Part A above. The sliver from the first pass was blended in a second pass through the draw frame with a sliver of equal weight prepared from a mass of commercially available 1.67 dtex per filament, round cross section crimped polyester staple fibers. Prior to carding numerous fiber bundles comprised of nonconvoluted fibers and having a corrugated crimp pattern were observed within the mass of commercially available staple fibers. The bundle crimp frequency of these nonconvoluted fiber bundles was determined to be 4.4 crimps per cm. (11.2 crimps per inch) and the bundle crimp index was determined to be 21.4%. The blended sliver was reprocessed in a third pass through the draw frame and then processed on a roving frame and a ring-spinning frame to make a 50/50 convoluted/ nonconvoluted blend yarn, designated as Yarn 3B. The properties of this yarn are listed in Table II.

Yarns 3A and 3B were knitted on a circular knitting machine to form 22-cut single knit plain jersey fabrics. The fabric made from Yarn 3A had a pleasing cotton-like hand indistinguishable from an authentic cotton fabric of the same construction.

The fabric made from Yarn 3B had the visual and tactile aesthetics of a polyester/cotton fabric of the same construction.

EXAMPLE 4

Poly(ethylene terephthalate) containing 0.3 wt. % TiO_2 and having an HRV of about 22 was extruded from a spinneret having 34 propeller-shaped orifices of the same dimensions as the orifices of the spinneret of Example 1. The spinneret temperature was ∿285°C and the extruded filaments were quenched with a cross flow of room temperature air at the rate of about 1.49 cubic meters per minute (52.5 cubic feet per minute) through a flat screen 25.4 cm. high having an area of 0.039 m^2. The extruded filaments were gathered into a yarn and wound up at a speed of 2652 m/min (2900 ypm). The as-spun yarn contained 34 filaments and had a linear density of 209 dtex.

Eight bobbins of the 209 dtex yarn were combined into a tow, which was drawn 1.55X through an aqueous bath maintained at a temperature of 71°C and then wound up as a package at 70 mpm (77 ypm). Immediately after leaving the aqueous bath the tow was passed in contact with a sponge, a ceramic guide, and a slot applicator from which a 10% aqueous solution of a finish comprising 49.0 wt. % isocetyl stearate, 24.5 wt. % sodium bis(2-ethylhexyl)sulfo-succinate, 24.5 wt. % of a 3 mole ethylene oxide condensate of stearyl alcohol, 1.0 wt. % triethanolamine, and 1.0 wt. % oleic acid was applied to the tow. The drawn tow was passed through a relaxer tube into which steam at 69 kPa (10 psi) was also fed, the tow being overfed into the tube and the filaments becoming convoluted in the tube, and then into a stuffer box crimper into which steam at 34.5

kPa (5 psi) was fed. The crimped tow was then dried at 65°C overnight and heat set at 205°C for 10 minutes. One-third of the tow was cut to 11.4 cm. (4.5 in.) staple fibers, another third to 12.7 cm. (5 in.) staple fibers, and the other third to 14.0 cm. (5.5 in.) staple fibers. In each case, numerous fiber bundles comprised of convoluted fibers and having a corrugated crimp pattern were observed within the mass of staple fibers. The properties of the staple fibers are listed in Table I. In each instance the mass of staple fibers had more than 1000 fiber bundles per kilogram.

The three cut lengths of staple fibers were blended and a spun yarn, designated as Yarn 4, was prepared on the worsted system. The properties of this spun yarn are listed in Table II.

EXAMPLE 5

Poly(ethylene terephthalate) containing 0.1 wt. % TiO_2 and having an HRV of about 22 was extruded from the spinneret of Example 1 at a spinneret temperature of 288°C and quenched with air at room temperature at the rate of 0.7 m^3/min. through the quenching apparatus of Example 1. The extruded filaments were gathered into a 300-filament yarn and wound up at a speed of 1830 m/min.

A tow was formed by combining 17 ends of the 300-filament yarn. The tow was drawn 2.0X through a 65°C water bath at a draw roll speed of 100 mpm (109 ypm), with the finish described in Example 2 being applied from a finish roll after the tow is drawn at a concentration which provided a finish level of 0.24 wt. % on the staple fiber product. A combined tow was made from four ends of the drawn tow, and two ends of the combined tow were fed through a stuffer box crimper at room temperature, after which the crimped tow was passed on a conveyor belt through a 4-zone relaxer oven in which the zone temperatures were maintained at 90°, 109°, 123°, and 140°C for a residence time of 8 minutes. The tow was then cut to a mass of staple fibers having a cut length of 3.8 cm. (1.5). The staple fibers were oversprayed with 0.20 wt. % of the finish composition decribed in Example 2, raising the total finish level to 0.44 wt. %. Examination of the staple fibers revealed that they were convoluted and contained crimp. Numerous fiber bundles comprised of convoluted fibers and having a corrugated crimp pattern were observed within the mass of staple fibers. The bundle crimp frequency was determined to be 4.9 crimps per cm. (12.4 crimps per inch) and the bundle crimp index was determined to be 9.3%. Other properties of the crimped, convoluted staple fiber product are listed in Table I. The mass of staple fibers contained more than 1000 fiber bundles per kilogram.

Crimped, convoluted staple fibers prepared as described above were processed on the cotton system from a picker lap through a conventional flat card system. At the beginning of the sliver preparation step the carding machine was started and the doffer speed and throughput were increased until the maximum card capability was attained at a doffer speed of 25 rpm and a throughput of 12.8 kg/hr. Continuous carding and coiling of the sliver formed from the crimped, convoluted staple fibers was readily attained with the carding machine operating at its maximum capability. Because of excess machine vibration the machine speed was then reduced somewhat and throughout the remainder of the run the sliver was prepared and coiled at a throughput of 10.7

kg/hr. The resulting sliver was processed through a draw frame in two passes, combining eight ends on each pass, and then through a roving frame. The roving, which had a twist of 0.21 turns per cm., was then processed into yarn on a ring spinning frame. The properties of the yarn are listed in Table II.

COMPARATIVE EXAMPLE

A tow was formed by combining 17 ends of the 300-filament yarn of Example 5, and the tow was drawn using the same finish and same conditions described in Example 5. A combined tow was made from four ends of the drawn tow. The combined tow, which had not been passed through a stuffer box crimper, was then passed on a conveyor belt through a 4-zone relaxer oven under the same conditions described in Example 5 and finally cut to a mass of staple fibers having a cut length of 3.8 cm. (1.5 in.). The convoluted staple fibers, which had a finish level of 0.17 wt. % when cut, were oversprayed with 0.20 wt. % of the finish composition described in Example 2, raising the total finish level to 0.37 wt. %. Examination of the individual staple fibers revealed that they were convoluted and contained crimp, even though no mechanical crimping step had been included in the preparation of the fibers. Numerous fiber bundles comprised of convoluted fibers were observed within the mass of staple fibers. However, no corrugated crimp pattern was observed in the fiber bundles, and the bundles were accordingly rated as having a zero bundle crimp frequency.

A sample of the staple fibers was submitted for determination of the crimp frequency of the individual staple fibers. In this determination, the ends of a single fiber are clamped and the fiber is held under a low tension, insufficient to straighten out the crimps. The total number of bends on one side of the fiber only, with respect to a line between the points on the fiber at which it is held at each end by the clamps, is counted and recorded as the number of crimps. The fiber is then gently straightened, taking care not to pull out the fibers beyond their straightened length, and the distance between the clamps is measured. The crimp frequency for the individual fiber is then calculated by dividing the number of crimps by the distance between the clamps. In the sample submitted, the average crimp frequency of twelve convoluted fibers measured individually was 3.9 crimps per cm. (9.9 crimps per inch); although, as noted above; the bundle crimp frequency for this sample was zero.

The staple fibers were also found to have a linear density of 2.2 dtex/fil, a propeller cross section with a fin W/T ratio of 4.9, and a range of 9 to 61 convolutions per cm. with an average of 27 convolutions per cm. Their crystallinity index was 42, their t/t_7 was 2.3/0.72, and their elongation was 42%.

Convoluted staple fibers prepared as described above were processed on the cotton system, using the same picker lap and flat card system employed in Example 5. At the beginning of the sliver preparation step the carding machine was started and the doffer speed and throughput were increased; however, at a throughput of 6.0 kg/hr. unstable operation occurred. Sliver could be drawn into the coiler for only short periods before continuity of the operation was interrupted by sliver breaks. The speed of the machine was reduced and throughout the remainder of the run the sliver was prepared and coiled at a throughput of 5.4 kg/hr.

The resulting sliver was processed through a draw frame in two passes and then through a roving frame as in Example 5. The roving, which had a twist of 0.21 turns per cm., was then processed into yarn on a ring spinning frame. The resulting yarn was a 236 dtex, single ply yarn having a twist of 7.5 Z turns per cm. and a boil-off shrinkage of 3.2%. The yarn had a skein breaking tenacity of 1.0 dN/tex and a Lea Product of 2118.

TABLE I

STAPLE FIBER PROPERTIES

	Example No.				
	1	2	3	4	5
Bundle crimp frequency, crimps/cm.	4.1	4.0	4.1	5.2	4.9
Bundle crimp index, %	16.2	17.6	12.9	34.0	9.3
Fin W/T ratio	3.9	3.7	3.7	4.9	4.9
Range of convolutions/cm.	8-72	11-46	18-74	7-37	14-56
Average convolutions/cm.	24	24	45	14	29
Crystallinity index	50	33	48	46	42
Linear density, dtex/fil	2.0	2.5	2.3	6.0	2.3
t/t_7 (dN/tex)	2.9/0.79	1.9/.67	2.2/0.63	1.4/0.52	2.3/0.63
Elongation, %	49	54	74	74	44
Staple length, cm.	3.8	3.2	3.8	11.4 12.7 14.0	3.8

TABLE II

SPUN YARN PROPERTIES

Yarn No.	Blend Level*	Twist, Turns Per cm.	Linear Density dtex/ no. of plies	Skein Breaking Tenacity, dN/tex	Lea Product	Boil-off Shrinkage, %
1A	100/0	7.6Z	227/1	1.25	2650	3.3
1B	100/0	9.4Z	148/1	0.96	2040	4.2
2	100/0	6.5Z	295/1	0.91	1930	4
3A	100/0	7.6Z	227/1	0.80	1710	11
3B	50/50	7.6Z	227/1	1.11	2350	7
4	100/0	Singles 2.8Z	440/2	0.55	1160	14
		Plied 3.5S				
5	100/0	7.5Z	234/1	0.98	2083	5.9

*Blend level = % convoluted fibers/% nonconvoluted fibers

CLAIMS

1. A mass of terephthalate polyester staple fiber, said staple fiber having a crystallinity index greater than about 10, a linear density of 1 to 6 decitex, a tenacity greater than 1 decinewton per tex, and a cross-sectional shape when cut perpendicular to the longitudinal dimension of the fiber comprising a stem portion and at least one fin portion, said at least one fin portion having a width at least 1.4 times its thickness, said at least one fin portion being convoluted around said stem portion to the extent of about 5 to 300 convolutions per centimeter of length, a portion of said staple fiber being present in the form of fiber bundles, said fiber bundles having a corrugated crimp pattern, a bundle crimp frequency of 2 to 12 crimps per centimeter of length and bundle crimp index of 5 to 40%, said fiber bundles being present in said mass to the extent of at least 1000 fiber bundles per kilogram of said mass.

2. A mass of staple fiber as claimed in claim 1, wherein the terephthalate polyester is polyethylene terephthalate.

3. A mass of staple fiber as claimed in either of claims 1 and 2 wherein the fiber cross-section is in a shape essentially as illustrated in any of FIGS. 2 to 6 of the accompanying drawings.

4. A mass of staple fiber as claimed in either of claims 1 and 2, wherein the fiber cross section is in the shape of a two finned propeller.

5. A blend of a mass of terephthalate polyester staple fiber as claimed in any one of claims 1 to 4 with other staple fibers, said blend containing at least 100 fiber bundles per kilogram, said bundles containing convoluted fibers and having a corrugated crimp pattern.

6. A blend as claimed in claim 5, wherein the other staple fibers comprise cotton fibers.

7. A blend as claimed in claim 5, wherein the other staple fibers comprise terephthalate polyester fibers having 2 to 12 crimps per centimeter.

8. A yarn spun from a mass of staple fiber as claimed in any one of claims 1 to 4 or a blend as claimed in any one of claims 5 to 7.

9. A fabric made at least in part from a yarn as claimed in claim 8.

FIG. 1

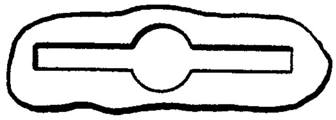

FIG. 2

FIG. 3

FIG. 4

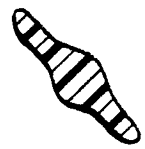

FIG. 5

FIG. 6

FIG. 7

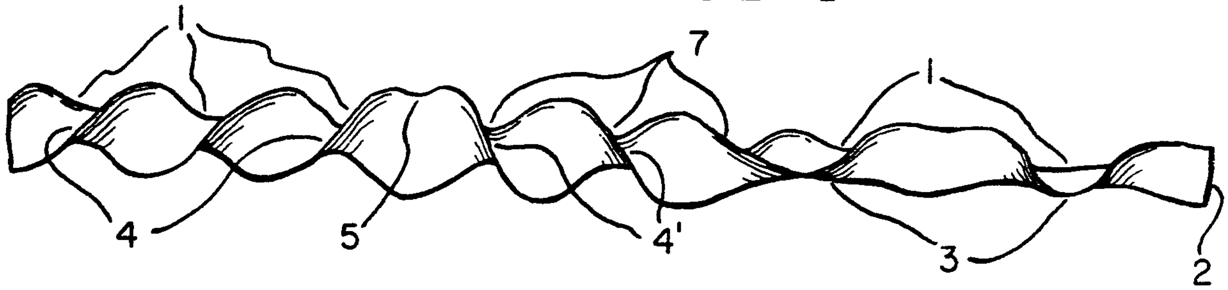

FIG. 8