

May 2, 1967

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3,316,612

PROCESS OF DRAWING AND CRIMPING ASYMMETRICALLY QUENCHED
POLYESTER FILAMENTS TO PROVIDE A COMPACT
RIBBON-LIKE TOW FOR SHIPPING AND
ENHANCED BULK IN END-PRODUCTS

Original Filed July 30, 1962

2 Sheets-Sheet 1

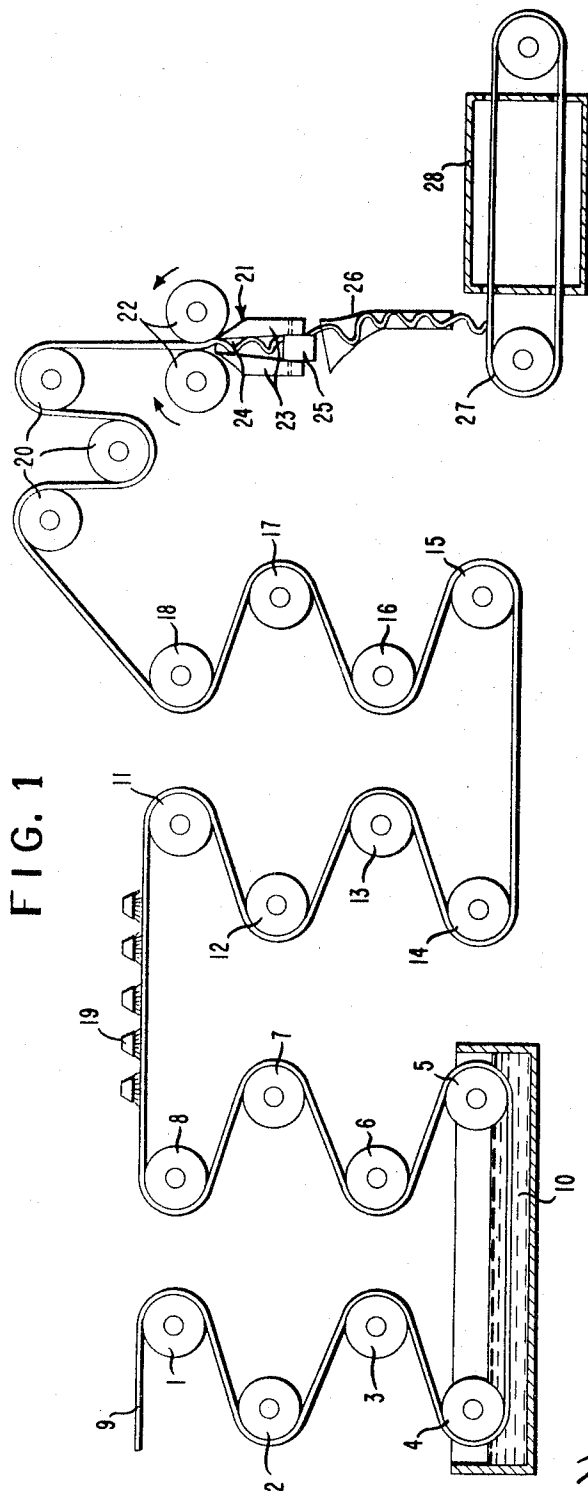


FIG. 1

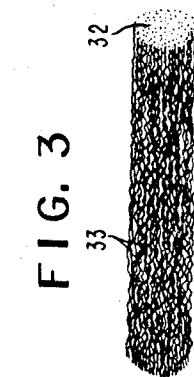


FIG. 2

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2 Sheets-Sheet 2

FIG. 4



FIG. 5

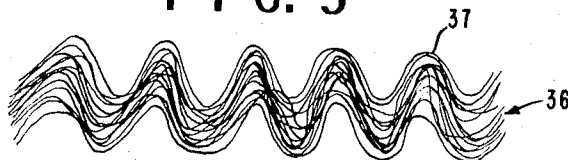
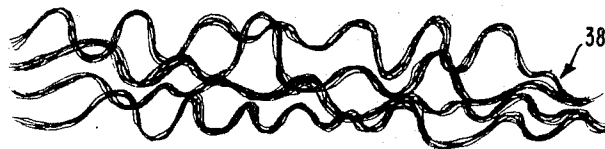


FIG. 6



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3,316,612

PROCESS OF DRAWING AND CRIMPING ASYMMETRICALLY QUENCHED POLYESTER FILAMENTS TO PROVIDE A COMPACT RIBBON-LIKE TOW FOR SHIPPING AND ENHANCED BULK IN END-PRODUCTS

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Original application July 30, 1962, Ser. No. 213,222, now Patent No. 3,235,442, dated Feb. 15, 1966. Divided and this application Oct. 12, 1965, Ser. No. 508,408
5 Claims. (Cl. 28—72)

This is a division of my application Ser. No. 213,222 filed July 30, 1962, which issued as U.S. Patent No. 3,235,442 on Feb. 15, 1966.

This invention relates to a novel crimped tow of a crystallizable linear condensation polyester, and to a novel process for forming it. The invention also concerns novel staple fibers cut from the crimped tow.

In a recent development in the field of polyester fibers, it has been found that crimped filaments of improved properties can be formed by extruding the molten polyester in the form of filaments, quenching the extruded filaments with a fluid in an asymmetric manner so that one side of each filament is solidified before the other side, and orienting the extruded filament. Asymmetric cooling of the filament may be achieved, for example, by employing as the quenching medium a jet of air or other gas directed upon one side of the extruded filament a short distance from the spinneret rather than by cooling the filament over a considerable distance with a current of air, as in conventional melt spinning. Although the as-spun filaments are straight and indistinguishable by sight from ordinary as-spun filaments, they show different optical properties; i.e., an asymmetrically quenched filament exhibits an asymmetric birefringence differential across the diameter of the filament as contrasted with a symmetric differential, or lack of any differential, associated with ordinary polyester filaments. When the asymmetrically spun filaments are drawn several times their extruded length and tension is released, they exhibit crimp of a three-dimensional or reversing helical nature unobtainable by conventional mechanical crimping methods. The three-dimensionally crimped filaments are highly valuable, especially when converted to staple fibers, for many important uses including the preparation of fabrics with improved bulk, cover, and wool-like aesthetics and as stuffing materials of enhanced bulk and softness for pillows and the like.

The fact that the asymmetrically quenched, three-dimensionally crimped filaments exhibit high bulk, although important for the production of end products of high quality, unfortunately leads to high costs in shipping tows of the filaments. The packaging density of the asymmetrically quenched tow may be as low as about 25% of the density of conventional tow. The asymmetrically quenched product also presents greater difficulties in processing as compared with conventional tow. Owing to its greater openness, the asymmetrically quenched tow is more susceptible to snagging on textile apparatus with which it comes into contact, as contrasted with conventional tow. In cutting the tow to form staple fibers, or in the production of converter sliver in the tow to top process, the cut length of the asymmetrically quenched staple fibers is frequently less uniform than in the conventional product. A product possessing the processing and shipping properties of conventional tow but having the improved bulk, cover, and wool-like aesthetics of the asymmetrically quenched fiber in finished articles has therefore been greatly desired.

It is an object of this invention to provide a crimped

polyester tow which, when converted to finished articles via conventional textile methods, exhibits a high degree of bulk and cover with wool-like aesthetics. Another object is to provide such a tow in a high density form having a shipping bulk comparable to that of conventional polyester tow and processing characteristics similar to conventional tow which, however, develops enhanced bulk and other desirable properties when processed into finished articles by conventional textile methods. A further object is to provide crimped polyester staple fibers having a high degree of bulk and good fiber aesthetics in the form of finished articles. Still another object is to provide a process for preparing a crimped polyester tow possessing substantially the same shipping density and processing characteristics of conventional polyester tow which, however, develops enhanced bulk during textile processing to form finished articles having excellent bulk. Other objects will appear as the description of the invention proceeds.

These objects are achieved by an improvement in the subsequent processing of undrawn, crystallizable, linear condensation polyester filaments which have an asymmetric birefringence differential across the filament diameters, e.g., produced by asymmetric quenching during melt-spinning of the filaments as disclosed in Kilian U.S. Patent No. 3,050,821, issued Aug. 28, 1962, and Lees U.S. Patent No. 3,061,874, issued Nov. 6, 1962. In the process of the present invention, a tow of these undrawn filaments is drawn at a draw ratio of about 2 to 5 times to orient the filaments, is maintained under sufficient tension to keep the filaments parallel and, with the filaments parallel, is mechanically crimped to form a ribbon-like tow of filaments having a two-dimensional crimp. Crimping methods conventionally used for imparting a mechanical crimp are suitable, and the product resembles conventionally crimped tow in having a preponderance of filaments substantially parallel to one another across the ribbon-like cross section of the tow. However, the products of this invention are characterized by having an asymmetric birefringence differential across the filament diameters, which extends all along the fiber length, to provide a surprising increase in bulk when they are mechanically worked during further processing into yarn, woven or knitted fabric, or filling material for stuffed articles.

The products of this invention include novel staple fibers cut from the tow. These differ from conventional staple converter products cut from tow crimped in a stuffing box crimper as disclosed, for example, in Hitt U.S. Patent No. 2,311,174 of Feb. 16, 1943. Such conventional staple fibers have a saw-tooth crimp form and a substantially symmetric birefringence differential across the diameters, or no birefringence differential at all. The staple fibers of the present invention have a substantially sinusoidal, two-dimensional crimp, as initially produced, and an asymmetric birefringence differential across their diameters.

The tow product of the invention is readily handled in subsequent process steps such as piddling, hot-oven relaxation, packaging in shipping cartons, unpacking from the cartons, and processing in a tow-to-top converter such as a Pacific converter. In case of processing and in shipping density the tow product of the invention is comparable to conventional mechanically crimped tow. However, during the preparation of staple yarn and fabric via conventional methods, a higher degree of bulk is achieved than with conventional mechanically crimped staple fibers, accompanied by improved cover and more wool-like aesthetics. The degree of bulk of the end products derived from the tow product of the invention is at least substantially equivalent to that of products derived from tows of asymmetrically birefringent filaments which have not been subjected to mechanical crimping, and data included

in Kilian U.S. Patent No. 3,050,821, issued Aug. 28, 1962, is generally applicable to the end products of the present invention. As previously noted, however, the asymmetrically birefringent tow which has not been subjected to mechanical crimping is already highly bulky in tow form, and has a low shipping density; it is also relatively more difficult to handle in processing, tends to snag and hang up during unpacking, and gives a converter product of less uniform cut length.

The tow product of the invention is readily distinguishable from conventional mechanically crimped polyester tow, since the latter filaments have a substantially symmetric birefringence differential across their diameter, or no birefringence differential at all; while filaments in the tow product of the invention exhibit an asymmetric birefringence differential across their diameters. The tow product is also readily distinguishable from asymmetrically birefringent tow which has not been mechanically crimped in accordance with this invention, since the latter is a relatively fluffy or bulky tow comprised of three-dimensionally crimped filaments which are grouped in numerous bundles of substantially parallel filaments, the filaments in different bundles not being parallel to each other, however. The tow accordingly lacks coherence, a length of it hanging free tends to assume a substantially round cross section. In contrast, the tow product of the invention forms essentially a single coherent bundle which, although crimped, is yet relatively flat and ribbon-like in appearance, with most of the filaments being substantially parallel throughout the bundle at most points; i.e., the crimps in the various filaments are substantially in register with one another.

The novel tow of the invention can, of course, be split lengthwise at various points across the bundle; but the ribbon-like bundle is surprisingly coherent and amenable to handling as a unitary structure in the form produced. The individual filaments exhibit a characteristic substantially sinusoidal, two-dimensional crimped form. The number of crimps per inch may vary but is preferably in the range of about 5 to about 15. The individual crimped filaments thus differ markedly from filaments of conventional polyester tow produced, for instance, with the aid of a stuffer box crimper, which exhibit a relatively sharp, saw-tooth, two dimensional crimped form. They also differ markedly from asymmetrically birefringent staple fibers which have been produced without the aid of a mechanical crimper, since the latter filaments exhibit a three-dimensional crimp having substantially a reversing helical form.

The staple fiber product of the invention is readily cut from the tow by conventional methods. The staple fiber product is similar to conventional mechanically crimped polyester staple in shipping density and in ease of processing, although readily distinguishable from the conventional staple fibers in having a substantially sinusoidal, two-dimensional crimped form and an asymmetric birefringence differential across their diameters. The staple fiber product of the invention is also readily distinguishable from asymmetrically birefringent staple fibers which have been produced without the aid of a mechanical crimper, since the latter fibers exhibit a three-dimensional crimp having substantially a reversing helical form. Such fibers are already relatively bulky, hence have a correspondingly much lower shipping density.

The term "tow," as used herein, refers to a large number of continuous, substantially parallel, synthetic filaments without definite twist collected in a loose, ribbon-like or rope-like form. Generally speaking, the minimum number of filaments to which the term "tow" is considered applicable is on the order of about one thousand, and normally there are 10,000 or more filaments. While there is no fixed maximum number, tows containing on the order of 1,000,000 filaments are frequently encountered, and there may be occasions to employ tows of 10,000,000 filaments or even more. The filaments may be

of round cross-section or of trilobal or other non-round cross section.

The nature of the invention will be more readily understood by reference to the following description taken in conjunction with the accompanying drawings in which

FIGURE 1 is a schematic illustration of the process of the invention and apparatus which may be used in carrying out the process of the invention,

FIGURE 2 is a view of a portion of the drawn, mechanically crimped, asymmetrically birefringent polyester tow bundle of the invention,

FIGURE 3 is a view of a drawn, asymmetrically birefringent polyester tow bundle of the prior art which has not been subjected to mechanical crimping.

FIGURE 4 is an enlarged view of conventional, mechanically crimped polyester staple fibers of the prior art which are not asymmetrically birefringent,

FIGURE 5 is an enlarged view of mechanically crimped, asymmetrically birefringent staple fibers of the invention, and

FIGURE 6 is an enlarged view of asymmetrically birefringent polyester fibers possessing a three-dimensional or reversing helical crimp, produced without the aid of a mechanical crimper.

Referring now to FIGURE 1, tow 9 comprises a large number of polyester filaments which have been melt extruded and jet quenched in an asymmetric manner, e.g., employing apparatus of the type disclosed by Lees in his U.S. Patent No. 3,061,874, issued Nov. 6, 1962. The tow is drawn by being passed from feed rolls 1 through 8, respectively, maintained at a given uniform peripheral speed and then around draw rolls 11 through 18, respectively, having a uniform peripheral speed considerably higher than that of the feed rolls. Between rolls 4 and 5 the tow passes through a pre-wetting vessel 10, which contains an aqueous bath which may be at room temperature or which may be heated to a temperature in the range 40-70° C. Additional quantities of the aqueous bath used in pre-wetting bath 10 are usually sprayed onto or otherwise supplied to rolls 5, 6, 7 and 8. Between rolls 8 and 11 the tow passes under spray nozzles 19, from which hot liquid spray is directed upon the moving tow, whereupon the tow is drawn to a length several times its original length in response to the tension imposed by the draw rolls. Preferably, the hot spray supplied to the tow is at a temperature equal to or higher than the second-order transition temperature, T_g , of the polyester of which the filaments are made.

After leaving the draw section, the tow is passed around puller rolls 20 and into a stuffer box crimper 21, comprising oppositely driven feed rolls 22, shoe plates 23, defining channel 24, and gate 25 mounted at one side of the channel at its exit. The gate impedes to a predetermined extent the free flow of the tow to the restricting channel and causes the yarn to fold back upon itself into the upper portions of the channel, thus forming a crimp or crinkle in the filaments comprising the tow bundle.

The crimped tow is passed through a traversing funnel 26 which lays the tow down on a conveyor 27, upon which the tow is passed through drying chamber 28. The dry tow may then either be packed as tow or cut to staple.

As previously described, in the absence of a mechanical crimper the asymmetrically birefringent filaments in the tow assume a three-dimensional helical crimp to a marked degree upon release of the tension of drawing. Upon employing a mechanical crimper in accordance with the process of the invention, the asymmetrically birefringent filaments are not released from the tension of drawing until imposition of the mechanical crimping step. It is believed that the tendency of the asymmetrically birefringent filaments to assume three-dimensional crimp simultaneously with the imposition of the mechanical crimp produces the disclosed novel sinusoidal crimp, as contrasted with either a three-dimensional crimp or a conventional saw-tooth mechanical crimp.

In a preferred embodiment of the process, a conventional stuffer box crimper is employed. However, a gear crimper or other mechanical crimping apparatus which imposes a two-dimensional crimp may also be employed.

FIGURES 2 and 3 illustrate the over-all appearance of two bundles of drawn asymmetrically birefringent polyester filaments. As shown in FIGURE 2, mechanically crimped tow 30 has the appearance of a single ribbonlike bundle having a fine wavy or crinkled configuration with most of the filaments being substantially parallel throughout the bundle at most points, so that the troughs and crests of the fine waves 31 appear to run transversely across the width of the tow bundle, giving it the appearance of a flat ribbon. The gross appearance of the tow bundle is very similar to that of a tow bundle of conventional mechanically crimped polyester filaments. As shown in FIGURE 3, the tow 32 comprised of drawn asymmetrically birefringent polyester filaments which have not been mechanically crimped has the appearance of a loose collection of small bundles 33 of filaments. The small bundles possess three-dimensional crimp and the filaments within these small bundles are substantially parallel to one another, but the bundles of filaments are not parallel with one another, giving the tow the appearance of a fluffy rope.

FIGURE 4 shows the saw-tooth crimp 35 of conventional mechanically-crimped polyester staple fiber 34 having a substantially symmetric birefringence differential across its diameter.

FIGURE 5 shows mechanically-crimped asymmetrically birefringent polyester staple fiber 36 prepared in accordance with the invention, having the characteristic sinusoidal crimp 37, which is substantially two dimensional.

FIGURE 6 illustrates asymmetrically birefringent polyester staple fiber 38 which has not been mechanically crimped. It possesses a reversing helical crimp which lacks definite inflection points in its curvature and is three dimensional in form.

In general, the invention is applicable to any crystallizable, linear condensation polyester. These comprise linear polyester containing in the polymer chain carbonyloxy linking radicals,



Polymers containing oxycarbonyloxy radicals are comprehended within this group. The polymers should be of fiber-forming molecular weight; usually, this implies a relative viscosity of about 10 or higher as conventionally measured in solution in a solvent for the polymers. A good solvent for most of the linear condensation polyesters is a mixture of 58.8 parts of phenol and 41.2 parts of trichlorophenol. Copolyesters, terpolyesters, and the like are intended to be comprehended within the term "polyesters."

Examples of crystallizable, linear condensation polyesters include polyethylene terephthalate, polyethylene terephthalate/isophthalate (85/15), polyethylene terephthalate/5-(sodium sulfo)isophthalate (97/3), poly(p-hexahydroxylylene terephthalate), polyhydroxyisobutyrate, poly(decahydronaphthalene-2,6-dimethylene 4,4'-biphenylate), polyethylene 2,6- or 2,7-naphthalenedicarboxylate, and poly(bicyclohexyl-4,4'-dimethylene 4,4'-biphenylate), as well as many others. Preferably, the polyester of which the tow and staple fibers of the invention are formed is a linear glycol terephthalate polyester. By this is meant a linear condensation polyester derived from a glycol and an organic acid in which the glycol component is comprised substantially of a dihydroxy compound of a divalent saturated hydrocarbon radical containing from 2 to 10 carbon atoms and the acid component is at least about 75 mol percent terephthalic acid.

The expression "second-order transition temperature," designated herein by the symbol " T_g ," is defined as the

temperature at which a discontinuity occurs in the curve of a first derivative thermodynamic quantity with temperature. It is correlated with yield temperature and polymer fluidity and can be observed from a plot of density, specific volume, specific heat, sonic modulus or index of refraction against temperature. T_g is sometimes also known as the "glass transition temperature" because it is the temperature below which the polymer exhibits glass-like behavior; above T_g the polymer is somewhat more rubber-like. A convenient method for determining T_g for a given sample of polymer is given by Pace in his U.S. Patent 2,556,295 (col. 3, line 24, to col. 4, line 19). The crystallinity of the polymer sample selected for measurement of T_g should be comparable with the crystallinity of the drawn filaments of the polymer.

Example I

Polyethylene terephthalate/5-(sodium sulfo)isophthalate (98/2) containing 0.3% TiO_2 and having a relative viscosity of 15.5 is extruded from a spinning block to form filaments. T_g for this polymer is approximately 76° C. Approximately 150,000 of the spun filaments are combined to form a tow bundle which is drawn at a draw ratio of 3 from a feed section comprising 8 feed rolls and a pre-wetting bath, maintained at approximately 50° C., through a draw zone with application of aqueous spray, maintained at 85° C., to a draw section comprising 8 draw rolls. The pre-wetting bath and hot aqueous spray each comprise a 1% aqueous solution of a textile finish agent comprised primarily of diethanolamine and triethanolamine salts. The filaments in the drawn tow have a denier per filament of 3.

"Tow A" is extruded and jet quenched from a block maintained at 285° C. through spinning apparatus of the type exemplified by Lees in his U.S. Patent No. 3,061,874, issued Nov. 6, 1962, at a spinning speed of 930 yards per minute, following which the tow is drawn as described above. Additional aqueous finish at room temperature is applied from sprays at the end of the spray draw zone. From the draw roll section, Tow A is passed as shown in FIGURE 1 around puller rolls and through a stuffer box crimper, following which it is laid down on a conveyor belt and passed through an oven maintained at 140° C. for an exposure time of 5 minutes. The product is a ribbonlike tow of the type illustrated in FIGURE 2; the individual filaments have about 3 crimps per inch of the sinusoidal form shown in FIGURE 5. When packed in shipping boxes, the tow readily packs to a density of 20 pounds per cubic foot. The individual filaments exhibit an asymmetric birefringence differential across the filament diameter when examined under a polarizing microscope. Improvements in processing into yarn and in fabric properties are disclosed subsequently.

For comparison, a "Tow B" is prepared in the same manner except that it is laid down directly on the belt from the puller rolls with a large air jet and is passed through an oven maintained at 140° C. for an exposure time of 5 minutes, the stuffer box crimping step being omitted. Use of the air jet was found necessary to help overcome difficulties in subsequent processing. Tow B is a loose, fluffy, rope-like tow as illustrated in FIGURE 3, and the filaments in the tow contain approximately 8 spiral crimps per inch of the type illustrated in FIGURE 6. When examined under a polarizing microscope, the individual filaments of the tow exhibit an asymmetric birefringence differential across the filament diameter. When the tow is packed in shipping boxes, it is found that Tow B packs to a density of only 5 pounds per cubic foot.

In another comparison, a tow designated as "Tow C" is extruded from a block maintained at 265° C. and quenched uniformly with cocurrent quenching air employing apparatus of the type exemplified by Dauchert in his U.S. Patent No. 3,067,458, issued Dec. 11, 1962, at a spinning speed of 1600 yards per minute, following which

the tow is drawn as described in the first paragraph of this example. The tow is passed around puller rolls and through a stuffer box crimper, following which it is laid down on a conveyor belt and passed through an oven maintained at 140° C. for an exposure time of 5 minutes. The product is a ribbon-like tow bundle which packs to a shipping density of 20 pounds per cubic foot. The filaments in the tow contain approximately 8 saw-tooth crimps per inch of the type illustrated in FIGURE 4. When examined under a polarizing microscope, the observed birefringence is not asymmetric as in the case of filaments taken from Tows A and B.

Ends of tow from four boxes of Tow A, the tow product of this invention, are combined and fed to a "Pacific" type tow-to-top converter employing a 3.5 inch cut. The converter sliver is collected in cans and the sliver is then subjected to gilling and four pin draftings. The pin draft sliver is slubbed and spun to 16/1 cc. yarn. 2 x 2 right hand twill fabrics are woven to a finished count of 66 ends x 62 picks and a finished weight of 6.4 oz./sq. yd. The woven fabric is desized, crabbed, scoured, dried, brushed and sheared, and semidecatized.

Four boxes of Tow C of conventional mechanically crimped tow are processed to fabric under identical process conditions and, in a third experiment, four boxes of Tow B of the jet-quenched tow prepared without using a stuffer box crimper are processed to fabric. In processing Tow B, however, an extra combing step is required after the second pin drafting step to remove imperfections and permit satisfactory further processing.

In comparing the results of processing the three tows, it is noted that Tow A and Tow C are easily withdrawn from their respective shipping boxes, while Tow B snags, entangles, and hangs up upon unpacking. The pin drafted sliver from Tow B is visibly less uniform and open than the pin drafted sliver from Tows A and C. The staple cut length of Tows A and C is more uniform than the staple cut length of Tow B; and measurement after the second pin drafting of "neps" (defined as small knots of fibers present in the sliver), and "caterpillars" (unopened groups of fibers still stuck together along substantially their entire length), shows that the incidence of such defects is much higher in Tow B than in Tows A or C. As noted above, the incidence of defects in Tow B is indeed so high that an extra combing step is required. The following table summarizes the incidence of defects in the processing of the three batches of tow and the properties of the resulting yarns and fabrics.

	Tow A (Jet Quenched, Mechanically Crimped)	Tow B (Jet Quenched, Not Mechanically Crimped)	Tow C (Con- ventional, Mechanically Crimped)
Stable cut length; fibers 2.5" or shorter	ca. 120	ca. 282	ca. 50
Neps per oz.	0.9	1.8	None
"Caterpillars," wt. percent	0.9	1.8	None
Yarn properties:			
Tenacity, g.p.d.	1.4	1.3	2.3
Lea Product	1,900	1,700	2,800
Fabric bulk (percent light transmitted)	1.02	1.06	1.20

Upon comparison of the three fabrics, it is observed that the fabrics prepared from Tows A and B are substantially equivalent and that both are bulkier, possess superior cover, and have a more wool-like hand than the fabric derived from Tow C. The improved bulk and cover of the fabrics prepared from Tows A and B is confirmed by the lower transmittance of visible light, as noted in the table above. The visible light transmittance is determined by measuring the amount of light passing through the fabric, from a source of white light, with the aid of a calibrated photocell.

Similarly, when Tows A, B and C are blended on the pin drafter with wool top to prepare 55% polyester/45% wool yarns, it is noted that the staple blend fabrics derived

from Tows A and B are bulkier, have greater covering power, and exhibit a more wool-like hand than the corresponding staple blend fabric derived from Tow C.

In an alternative preparation of Tow B, the drawn jet quenched tow is laid down on the conveyor belt with a traversing funnel, omitting the air jet as well as the stuffer box crimper. The tow so produced has a shipping density of about 10 pounds per cubic foot, as contrasted with only 5 pounds per cubic foot in the run described above. However, when the tow laid down without the air jet is passed through the Pacific converter, no coherent sliver at all is produced, owing to large and numerous "caterpillars" and other fiber defects.

Example II

Polyethylene terephthalate containing 0.3% TiO₂ and having a relative viscosity of 25 is extruded from a spinning block maintained at 296° C. through spinning apparatus of the type exemplified by Lees in his U.S. Patent No. 3,061,874, issued Nov. 6, 1962, at a spinning speed of 400 yards per minute to form filaments. T_g for this polymer is approximately 78° C. Approximately 6000 of the spun filaments are combined to form a tow bundle designated as "Tow D" which is drawn at a draw ratio of 3.2 from a feed section comprising 12 feed rolls through an aqueous bath, containing 1% textile finish agent as in Example I and maintained at 95° C., to a draw section comprising 4 draw rolls and a pinch roll. From the draw roll section the tow is passed around puller rolls and through a stuffer box crimper, following which it is dropped onto a tray and heated at 140° C. for 6 minutes in an oven. It is then passed through a cutter wherein it is cut to 2" staple fibers designated as "Staple Fibers D." The fibers have a denier per filament of 4.75 and exhibit an asymmetric birefringence differential across the fiber diameter when examined under a polarizing microscope. They have a sinusoidal crimp of the form shown in FIGURE 5.

Eighteen-ounce lots of Staple Fibers D are garnetted and made up into pillows in cotton ticking having a finished size of 20" x 26". The pillows exhibit good initial bulk and outstanding durability of bulkiness after prolonged wear.

For comparison, a tow designated as "Tow E" is prepared in the same manner as Tow D up to and including the drawing step. From the draw roll section, Tow E is passed through an air jet to remove excess moisture (omitting the stuffer box crimping step) and cut to 2" staple fibers designated as "Staple Fibers E," which are heated at 140° C. for 10 minutes in an oven. They have a denier per filament of 4.75 and, when examined under a polarizing microscope, exhibit an asymmetric birefringence differential across the fiber diameter. Their crimp is of the spiral form depicted in FIGURE 6.

In another comparison, a tow designated as "Tow F" is formed from 6000 filaments extruded from a block maintained at 296° C. and quenched uniformly with co-current quenching air employing apparatus of the type exemplified by Dauchert in his U.S. Patent No. 3,067,458, issued Dec. 11, 1962, at a spinning speed of 1200 yards per minute, following which the tow is drawn at a draw ratio of 3.8, passed through the stuffer box crimper, and heated at 140° C. for 6 minutes in the manner of Tow D. It is then passed through a cutter wherein it is cut to 2" staple fibers having a denier per filament of 4.75 and designated as "Staple Fibers F." These fibers are not asymmetrically birefringent as observed under a polarizing microscope. They have a saw-tooth crimp of the type illustrated in FIGURE 4.

Eighteen-ounce lots of Staple Fibers E and F are garnetted and made up into pillows in cotton ticking in the same manner employed to make the pillows from Staple Fibers D as described above. Each pillow is then subjected to compression testing under a 4" diameter presser foot depressed at the rate of 10" per minute. In the first cycle, the presser foot is depressed until a load of 20

pounds is reached. After holding at this load for one minute, the presser foot is retracted. The zero-load pillow height is then taken and the presser foot is again depressed, taking additional pillow height readings at loads of 10 pounds and 20 pounds.

The pillows are then subjected to a simulated wear test wherein the pillows are rotated on a turntable at a rate of one revolution each two minutes while they are struck in rapid succession by four 36 square inch presser feet (12" x 3") mounted on pistons applied at 80 pounds pressure during an interval of 1.5 seconds followed by a 2.5 second interval free from pressure. After one hour of mechanical working of these successive 4-second cycles, the pillows are again subjected to compression testing, observing the second-cycle pillow heights at zero, 10-pound, and 20-pound loads. The following table summarizes the observed results.

Second Cycle Pillow Heights	Staple Fibers D (Jet Quenched, Mechanically Crimped)	Staple Fibers E (Jet Quenched, Not Mechanically Crimped)	Staple Fibers F (Conventional, Mechanically Crimped)
New Pillows:			
Zero load, in.	8.7	8.8	7.1
10-pound load, in.	4.3	4.9	2.7
20-pound load, in.	2.7	3.2	1.5
Mechanically Worked Pillows:			
Zero load, in.	6.0	5.2	5.5
10-pound load, in.	2.4	2.1	1.6
20-pound load, in.	1.5	1.2	0.9

As shown in the above table, each of the jet quenched fiber samples exhibits superior bulk retention under load as contrasted with the conventional fibers (Staple Fibers F). Surprisingly, the jet quenched, mechanically crimped fibers of the invention (Staple Fibers D) exhibit good initial bulk and outstanding durability of bulkiness upon exposure to mechanical working, the latter being superior to jet quenched fibers which have not been mechanically crimped.

Since many different embodiments of the invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited by the specific illustrations except to the extent defined in the following claims.

I claim:

1. In the process of forming filaments of crystallizable linear condensation polyester material by extruding the molten polyester in the form of filaments, asymmetrically quenching the extruded polyester with fluid to form filaments having an asymmetric birefringence differential across the filament diameters and drawing a tow of said filaments at a draw ratio of about 2 to 5 times to orient the filaments, the improvement of maintaining the drawn filaments under sufficient tension to keep them parallel, and

mechanically crimping the tow of parallel filaments to form a ribbon-like tow of substantially parallel filaments having a two-dimensional crimp.

2. A process as defined in claim 1 wherein the mechanically-crimped, ribbon-like tow is to cut to form staple fibers characterized by having a substantially sinusoidal, two-dimensional crimp and an asymmetric birefringence differential across the fiber diameters.

3. A process as defined in claim 1 wherein the filaments are composed of a linear glycol terephthalate polyester.

4. A process as defined in claim 1 wherein the tow of parallel drawn filaments is stuffer-box crimped to form the ribbon-like tow of crimped filaments.

5. In the process of forming filaments of crystallizable linear condensation polyester material by extruding the molten polyester in the form of filaments, asymmetrically quenching the extruded polyester with fluid to form fila-

ments having an asymmetric birefringence differential across the filament diameters and warm, wet drawing a tow of said filaments at a draw ratio of about 2 to 5 times to orient the filaments, the improvement of maintaining the drawn, wet filaments under sufficient tension to keep them parallel, stuffer-box crimping the tow of parallel wet filaments and then drying the filaments to form a ribbon-like tow of substantially parallel filaments having a two-dimensional crimp.

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