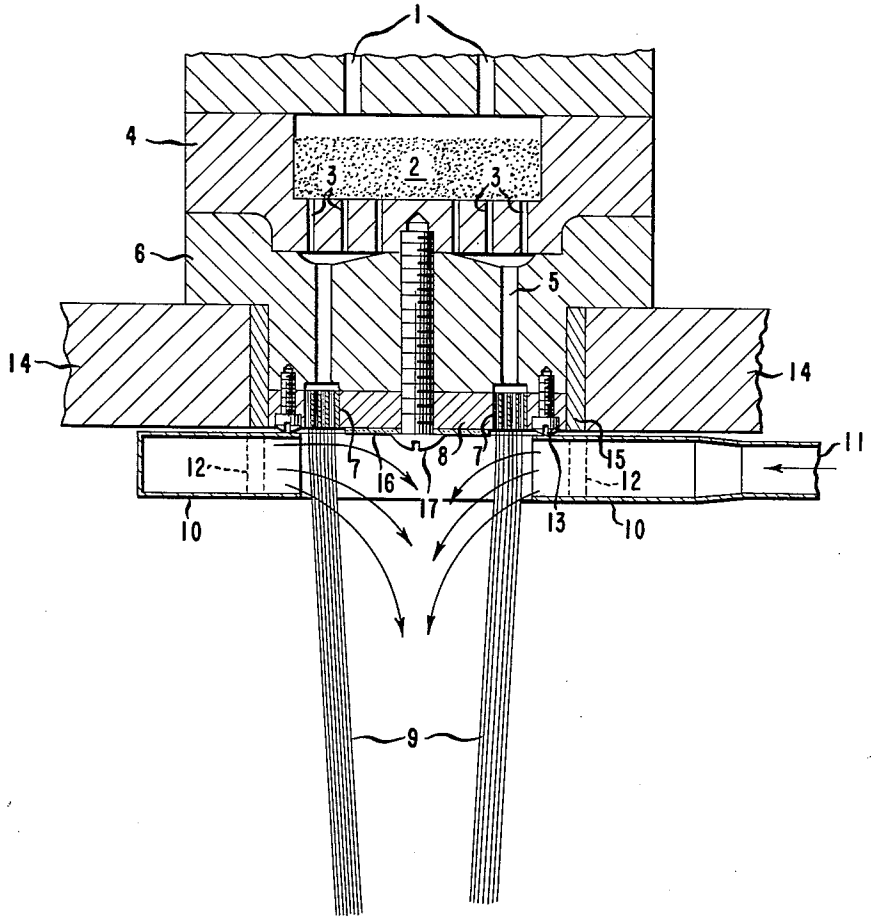
Aug. 28, 1962 J. J. KILIAN 3,050,821

HIGH BULK TEXTILE FIBERS

Filed Jan. 8, 1960



INVENTOR

JOSEPH J. KILIAN

BY Frank C. Hilberg

ATTORNEY

United States Patent Office

3,050,821

Patented Aug. 28, 1962

3,050,821

HIGH BULK TEXTILE FIBERS

Joseph J. Kilian, Covington, Va., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

Filed Jan. 8, 1960, Ser. No. 1,302
2 Claims. (Cl. 28—82)

This invention relates to novel crimped staple fibers composed of linear terephthalate polyesters, especially polyethylene terephthalate.

Polyethylene terephthalate, the preparation of which is described by Whinfield and Dickson in their U.S. Patent 2,465,319, has attracted wide commercial interest for many uses owing to its high tenacity, crease resistance, low moisture absorption, and other valuable properties. In one highly important commercial aspect of the technology, polyethylene terephthalate filaments are converted to crimped tow or to crimped staple fibers which find use not only in the preparation of knitted or woven fabrics but also as stuffing materials for pillows and other articles and for use in felts and other non-woven fabrics. It has been previously established that crimped fibers may be prepared not only by mechanical crimping means but also by carrying out the extrusion step or other yarn processing steps in various controlled ways. For example, Hebeler in his U.S. Patent 2,604,689 describes the production of crimped fibers of polyethylene terephthalate or its copolyesters by spinning the filaments at high speeds and then heat-treating the filaments.

Despite the versatility of staple fibers composed of polyethylene terephthalate and its allied copolyesters, various limitations in the product have been recognized which have tended to restrict its entry into certain end use situations. For example, the preparation of satisfactory flannel-type fabrics requires a degree of "cover" unobtainable on a commercial basis with staple yarns prepared from conventional crimped polyester fibers blended with wool. Improved bulking characteristics for crimped polyester tow or staple fibers used as stuffing materials have also been desired.

It is an object of this invention to provide novel crimped filaments and fibers composed of linear terephthalate polyesters, particularly polyethylene terephthalate. Another object is to provide crimped polyethylene terephthalate staple fibers from which fabrics having a high degree of cover may be formed. A further object is to provide crimped polyethylene terephthalate staple fibers which exhibit a high degree of bulk when employed as filling material for stuffed articles. An additional object is to provide crimped polyethylene terephthalate filaments in the form of tow exhibiting a high degree of bulk when employed as a filling material. Other objects will be apparent from the following description and claims.

These objects are achieved by the product of the present invention. The product comprises a crimped filament produced by spinning a molten linear polyester comprised substantially of polyethylene terephthalate to form filaments, quenching the filaments unsymmetrically by directing a jet of air against one side of the filaments as they emerge from the spinneret orifice to produce solidified filaments exhibiting differential birefringence across the width of the filaments, drawing the spun filaments to produce tenacious filaments having a three-dimensional crimp, and heating the drawn filaments to increase the crimp level. The crimped filaments of the invention are further characterized by drawn deniers in the range 1 to

6 (denier per filament), tenacities in the range 2 to 4.5 grams per denier, break elongations in the range 15 to 45%, initial modulus values in the range 500 to 1000 kg./mm.^{2}, compliance ratios in the range 0.4 to 0.8, and crimp index values in the range 15 to 70%.

One embodiment of the invention comprises a crimped tow exhibiting a high degree of bulk produced by associating a multiplicity of the spun filaments to form a tow and drawing and heating the tow so formed. A preferred embodiment of the invention comprises staple fibers formed by drawing the tow comprised of the spun filaments to produce the crimp, cutting the tow to form staple fibers, and heating the staple fibers to increase their crimp level. Surprisingly, the degree of crimp is enhanced if the cutting step precedes rather than follows the heating step. The crimp is three dimensional in nature and might best be described as a reversing helical crimp.

Various terms employed herein with respect to the novel product are defined below.

The initial modulus, which is represented herein by the symbol M_i, is defined as the slope of the first reasonably straight portion of a stress-strain curve of a fiber obtained by plotting tension on a vertical axis against elongation on a horizontal axis as the fiber is being elongated at the rate of 10% per minute under standard conditions of temperature (21° C.) and humidity (60% RH). The first reasonably straight portion is usually also the steepest slope to be found on the curve. Values for M_i as reported herein are in units of kg./mm.^{2} per 100% elongation.

The compliance ratio (CR) is associated with the shape of a stress-strain curve and is a measure of the rate of change of compliance with elongation. Compliance is defined as elongation divided by tension in kg./mm.^{2}. This property is measured by determining the average rate at which compliance changes in the range 5 to 10% elongation and is computed by the following formula:

$$CR=\frac{1}{5}(10/\text{tension at } 10\% \text{ elongation}-5/\text{tension at } 5\% \text{ elongation})$$

The crimp index is used as a measure of the extent of crimp of a fiber or bundle of fibers. The required data are obtained by measuring the length of the fibers hanging under an added load of 0.1 g.p.d. for a period of 2 seconds (length A), under which condition they are held straight, and measuring the length of the same fibers hanging under no added weight after they have relaxed for 15 seconds from the first extension (length B). The crimped tow from which the staple fibers are derived may be used in place of the fibers. The crimp index is calculated in accordance with the formula

$$\text{Crimp Index}=\frac{A-B}{A}\times 100\%$$

The tenacity and break elongation of the staple fibers are determined by conventional means.

In accordance with the invention, the linear polyester from which the staple fibers are formed is comprised substantially of polyethylene terephthalate. By this is meant a synthetic linear glycol-dicarboxylate polyester wherein at least about 75% of the recurring structural units of the polyester are polyethylene terephthalate structural units. The linear polyester thus has the general formula HO—G—(OOC—A—COO—G)$_y$—OH, where —G— and —A— are divalent organic radicals corresponding, respectively, to the radicals in the initial glycol,

$G(OH)_2$, and in the initial dicarboxylic acid, $A(COOH)_2$, and y is a number sufficient that the polymer is of fiber-forming molecular weight; at least about 75% of the —G— radicals being ethylene radicals and at least about 75% of the —A— radicals being terephthalate radicals. A relative viscosity of at least about 10 is required in order that the polymer be of fiber-forming molecular weight. The terephthalate radical may be the sole dicarboxylate constituent of the recurring structural units, or up to about 25% of the recurring structural units may contain other dicarboxylic radicals, such as the adipate, sebacate, isophthalate, 5-(sodium sulfo)isophthalate, bibenzoate, hexahydroterephthalate, diphenoxyethane-4,4'-dicarboxylate, or p,p'-sulfonylbibenzoate radicals, derived from the corresponding dicarboxylic acids, or ester-forming derivatives thereof. Similarly, ethylene glycol may be the sole glycol constituent of the polyester, or up to about 25 mol percent of another glycol may be used, such as tetramethylene glycol, hexamethylene glycol, decamethylene glycol, 2,2-dimethylpropanediol, cis- or trans-p-hexahydroxylylene glycol, diethylene glycol, bis-p-(β-hydroxyethoxy)benzene, bis-1,4-(β-hydroxyethoxy)-2,5-dichlorobenzene, or bis-1,4-(β-hydroxyethoxy)-2,5-difluorobenzene.

The invention will be more readily understood by reference to the following description taken in conjunction with the accompanying drawing wherein:

The FIGURE is a sectional elevation taken through a spinneret assembly which may be used to prepare the product of the invention.

Referring now to the figure, molten polymer is introduced through inlets **1** and forced through sand pack **2**, which may be build up in conventional manner from screens and various particle sizes of sand as described in U.S. Patent 2,266,368 to Hull et al. The polymer then flows through channels **3** in retaining member **4** and through channels **5** in distribution member **6** to orifices **7** in spinneret **8**. Filaments **9**, which are closely spaced in a series of concentric rings owing to the dense spacing of the spinneret orifices in concentric circles are immediately quenched by a strong flow of gas from annular nozzle **10**. The gas enters the annular nozzle through conduit **11** and flows through foraminous members **12** across the filament bundle as indicated by the arrows. The spinneret is held by bolts **13** to the distribution member **6**, which in turn rests upon supporting member **14**.

Band heater **15** may be used to control the temperature of the spinneret independently of the flow of polymer, which heats the spinneret, or the quenching gas, which cools it. Excessive cooling of the spinneret is prevented by a circular disc **16** of reinforced insulation held to the face of the spinneret by machine screw **17**, which also acts to hold together the retaining member **4**, the distribution member **6**, and the spinneret in the desired alignment.

After the filaments are spun, they may be drawn in conventional manner. For example, the filaments may be combined in the form of a tow and drawn in a hot aqueous spray. A preheating bath may be used. The filaments may also be drawn in the form of yarn bundles on conventional apparatus such as the hot pin apparatus disclosed by Kinney in his United States Patent 2,874,410.

The following examples are cited to illustrate the invention, although they are not intended to be limitative.

EXAMPLE 1

Spontaneously crimped staple fibers are produced in a series of experiments for which the results are summarized in Table I, the polymer employed being polyethylene terephthalate in entries 1—8 in the table and polyethylene terephthalate/5-(sodium sulfo)isophthalate (98/2) in entries 9—11 in the table. Polymer flake having the relative viscosity indicated in the table is melted and the melt (maintained at a temperature of about 290° C.) is extruded through a spinneret supplied with auxiliary heat sufficient to maintain good continuity of spinning by an electric band heater around the circumference of the spinneret. The spinneret contains 900 round orifices, each 0.007 inch in diameter, arranged on 6 concentric circles whose radii differ by 0.052 inch each, the smallest circle having a radius of 1.437 inches. The orifices are located at the intersections of radii of the spinneret spaced at angular intervals of 1° 12′ with the concentric circles, alternate intersections being skipped to provide a staggered pattern of orifices having center-to-center spacings on the circles varying from about 0.060 inch in the inner circle to about 0.071 inch in the outer circle.

The extruded filaments are quenched with air at room temperature from an annular quenching nozzle 4⅛ inches in inside diameter and having an opening 0.5 inch high (1 inch high in entries 7 and 8 in the table) spaced 3/16 inch below the spinneret face by a ring of aluminum foil and heavy asbestos cloth. The quenched filaments are wound at the speeds indicated in the table.

The individual as-spun filaments, when examined under a polarizing microscope, exhibit a refractive index differential from one side of the filament to the other. The spun fibers are combined to a tow, passed through an aqueous bath containing a textile finish agent, drawn 3—3.5X in an aqueous spray at 95° C., and piddled into an open container. Upon release of the tension of drawing, it is observed that the filaments exhibit a high level of three-dimensional crimp. The filaments are than cut to 2.2-inch lengths and relaxed for 15 minutes in a hot air oven maintained at 140° C. The relaxed filaments exhibit an even higher level of helical crimp than the as-drawn filaments. When examined under a polarizing microscope, the individual filaments again exhibit a refractive index differential from one side of the filament to the other. The properties of the staple fibers are indicated in the table.

Table I

	Polymer Relative Viscosity	Spin. Speed, y.p.m.	PROPERTIES OF RELAXED YARN								
			Break Elong., Percent	Crimp Index, Percent	Spiral Crimps Per Crimped in.	Yarn, d.p.f.	Tenacity, g.p.d.	Tensile Strength, kg./mm.²	M_i, kg./mm.²	CR	Tensile Recovery From 3% Extension
1	20.6	400	43	51	8.0	4.2	2.2	28.7	574	0.7	91
2	20.6	400	42	34	3.9	3.7	3.0	39.1	626	0.5	86
3	20.6	520	19	55	8.9	3.0	2.6	33.9	509	0.5	80
4	20.6	520	34	36	4.2	3.0	3.0	39.1	665	0.5	87
5	31.2	310	28	53	12.8	4.4	3.3	43.0	613	0.5	74
6	31.2	310	30	40	5.8	5.1	2.7	35.2	561	0.6	77
7	31.2	511	31	54	11.3	3.3	3.7	48.2	587	0.6	77
8	31.2	390	30	45	8.6	3.5	4.2	54.7	600	0.6	81
9	16.4	450	21	53	14.0	3.1	2.9	37.6	625	0.5	71
10	17.8	400	36	28	5.9	2.6	2.7	35.2	590	0.5	75
11	16.0	400	18	38	7.6	3.1	2.4	31.3	555	0.6	76

EXAMPLE 2

A quantity of the crimped fibers of entry 10 in Table I are dyed a navy color, blended with an equal quantity of dyed wool (Australian 64—70's), and spun as 31/1 c.c. with 15 S twist, after which two ends of the yarn are plied with a 13 Z twist. The yarns are then woven into a 2 x 2 right hand twill fabric containing 64 ends and 62 picks per inch. The greige fabric is scoured at 212° F., napped lightly, fulled, scoured again, sheared, pressed, and semi-decated. The finished fabric contains 79 ends and 68 picks per inch and has a weight of 7.23 ounces per square yard. The fabric is observed to have a flannel-like surface and a bulky hand.

The procedure is repeated, substituting for the fibers of Table I (three-dimensional crimp) an equal quantity of mechanically crimped commercially available fibers of the same polymer having the same denier and fiber length. The surface cover of the control fabric prepared in this way is substantially less dense than the surface cover of the fabric prepared from the fibers having three-dimensional crimp, and the hand of the control fabric is substantially less bulky. Measurement of the reflectance of light from the twill line by scanning a narrow strip of fabric with a continuously recording reflection densitometer through a narrow slit gives an average reflectance amplitude of 113 units for the control fabric and 58 units for the fabric prepared from the helically crimped fibers, indicating that the weave pattern is approximately twice as prominent in the control fabric as in the test fabric as measured by light reflectance. Men's slacks tailored from the test fabric and control fabric are worn for a total of 600 hours each under conditions of normal day-to-day use. At the end of this period the control fabric is bare while the fabric containing the helically crimped fiber has substantial residual surface.

EXAMPLE 3

Quantities of the polyester fibers having three-dimensional crimp (test item) employed in Example 2 and mechanically crimped commercially available polyester fibers (control item) employed in Example 2 are made up into pairs of fabrics, using identical procedures for yarn and fabric preparation for each member of a given pair of fabrics. Three fabric types are prepared: 100% polyester tropical fabrics, 55% polyester/45% wool tropical fabrics, and 65% polyester/35% rayon gabardine fabrics. The properties of the resulting fabrics are as follows:

Table II

Fabric Type	Percent Poly-Ester	Crimp	Fabric Weight (oz./yd.²)	Compression Constant	Bending Length (cm.)
Tropical	100	3-Dimensional	5.1	1.28	1.63
Do	100	Mechanically Crimped	5.4	1.05	1.72
Polyester/Wool Tropical	55	3-Dimensional	6.6	1.53	1.50
Do	55	Mechanically Crimped	6.8	1.40	1.60
Polyester/Rayon Gabardine	65	3-Dimensional	7.5	1.57	1.60
Do	65	Mechanically Crimped	7.4	1.34	1.68

The compression constant is a determination of low pressure bulk in accordance with the general method described in the Textile Research Journal, vol. 13, page 108 (1953). In this determination, high values are indicative of a high degree of bulk. The bending length is measured in accordance with the general method described by Pierce in J. Text. Inst., vol, 21, T377 (1930). In this determination, low values are indicative of low fabric stiffness.

EXAMPLE 4

Eighteen ounces of the fibers of entry 2 of Table I (three-dimensional crimp) are made up into a pillow in nylon ticking having a finished size of 19" x 25" (test item). A similar pillow is made up from 18 ounces of mechanically crimped, commercially available polyester fibers in nylon ticking having a finished size of 19" x 25" (control item). Each item is 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 50 lbs. is reached and the presser foot is then retracted. The test pillow rebounds to a height of 7.3" as contrasted with only 6.3" rebound for the control pillow. When the presser foot is again depressed, each pillow has a height of 2.4" at 10 lbs. load and 1" at 25 lbs. load. The greater bulk and softness of the test pillow is demonstrated by its greater height under zero load, with height equivalent to the control pillow under 10 lb. and 25 lb. loads. The test pillow is also adjudged subjectively to be softer than the control pillow.

Similar results are obtained when the experiment is repeated, employing as a stuffing material the novel fibers of the invention in the form of a tow having three-dimensional crimp and using a mechanically crimped tow as a control stuffing material.

Crimped tow and crimped staple fibers prepared in accordance with the invention possess excellent bulking properties. As compared with previously known polyethylene terephthalate crimped fibers, a smaller weight of the fibers of the invention suffices to produce the same bulk, so that the resulting filled articles are lighter in weight. Articles filled with the fibers of the invention also exhibit superior load-compression curves, such that even under relatively heavy loads the articles retain resilience and are not flattened out. Pillows or cushions prepared from the fibers have a soft, luxurious feel and are completely washable.

When employed for textile end uses, the fibers of the invention exhibit excellent crimp retention through the standard textile processing steps and in the resulting fabrics, whether the fibers are used alone or in the form of a blend with wool or other fibers. The resulting fabrics are characterized by interfiber entanglement to an unusually high degree, leading to a degree of loft and "cover" unobtainable with previously known polyethylene terephthalate crimped staple fibers. With the aid of the fibers of the invention, flannels and other suiting fabrics have become practicable which previously were unsatisfactory when prepared from polyethylene terephthalate fibers.

It will be apparent that many widely different embodiments of this invention may be made without departing from the spirit and scope thereof, and therefore it is not intended to be limited except as indicated in the appended claims.

I claim:

1. A high bulk textile material comprising synthetic linear glycol-terephthalate filaments having, when relaxed for 15 minutes in a hot air oven at 140° C., a tenacity of 2 to 4.5 g.p.d. in the 1 to 6 denier per filament range; a break elongation in the range of 15% to 45%; an initial modulus between 500 and 1000 kg./mm.²; a compliance ratio between 0.4 and 0.8; and about 4 to 13 helical crimps per inch with a crimp index value between 15% and 70%; and further characterized by having a differential birefringence across the width of the filaments.

2. The material of claim 1 in which the polymer from

which the filaments are made has the general formula $HO—G—(OOC—A—COO—G)_y—OH$, where —G— and —A— are divalent organic radicals corresponding, respectively, to the radicals in the initial glycol, $G(OH)_2$, and in the initial dicarboxylic acid, $A(COOH)_2$, and y is a number sufficient that the polymer is of fiber-forming molecular weight; at least about 75% of the —G— radicals being ethylene radicals and at least about 75% of the —A— radicals being terephthalate radicals.

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