

Nov. 25, 1958

A. L. BREEN

2,861,319

INTERMITTENT CORE FILAMENTS

Filed Dec. 21, 1956

2 Sheets-Sheet 1

Fig. 1

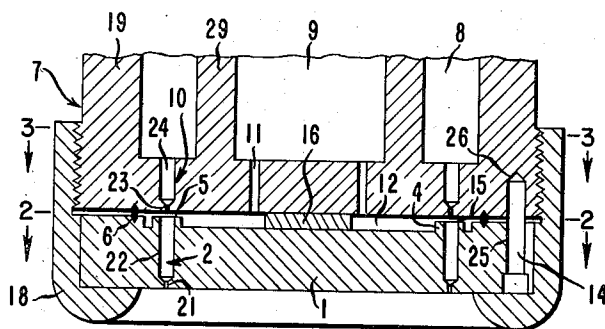


Fig. 2

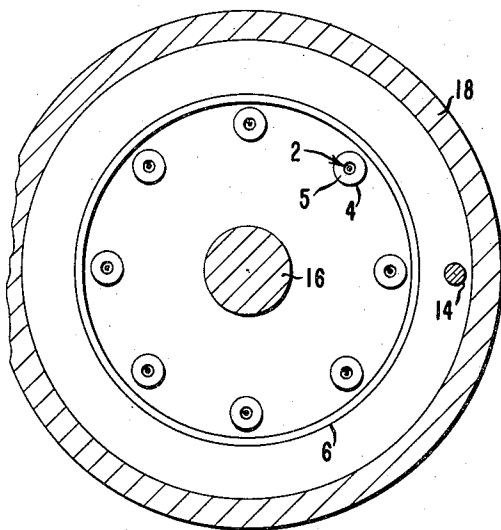


Fig. 3

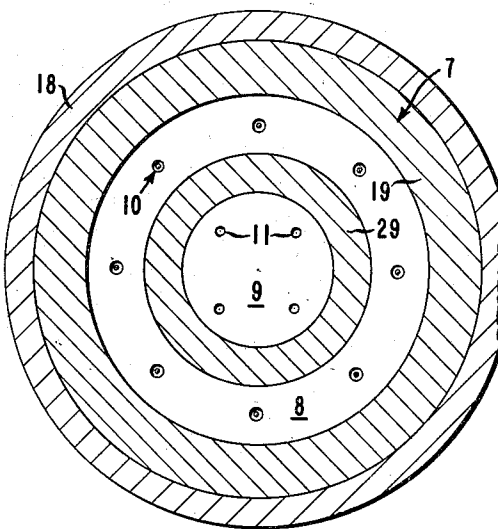
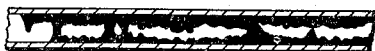


Fig. 6



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2 Sheets-Sheet 2

Fig. 4

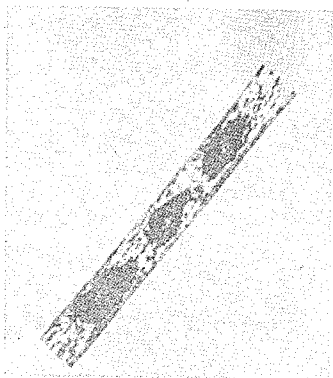


Fig. 5

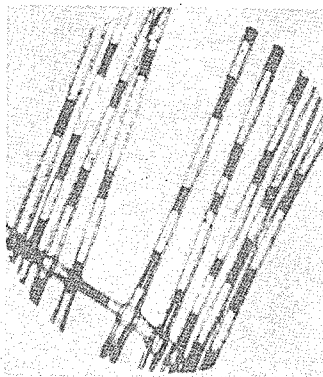


Fig. 7

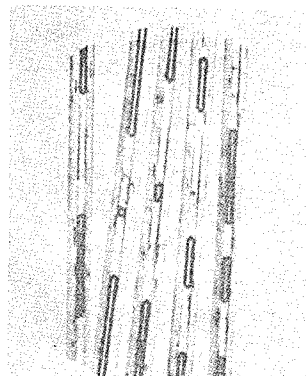


Fig. 8

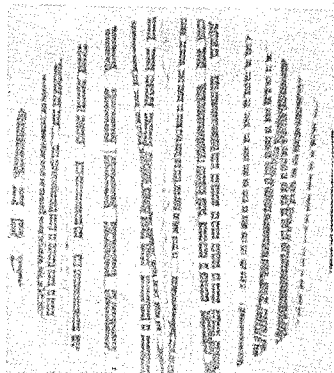


Fig. 9

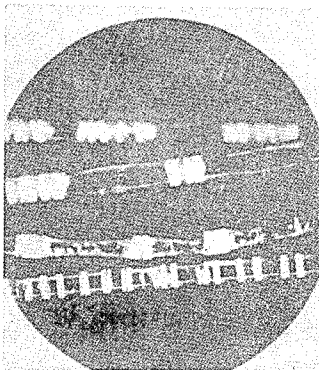
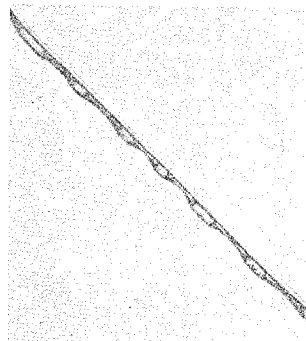


Fig. 10



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INTERMITTENT CORE FILAMENTS

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Application December 21, 1956, Serial No. 629,862

12 Claims. (Cl. 28—82)

This invention is concerned with novel porous filaments and a process for making them.

The value of filaments containing air spaces or the like has long been recognized. Such filaments generally have a lower luster and lower density than solid filaments, and can be used to make fabrics that are warmer due to the enclosed gas than conventional solid filaments. It has been suggested that hollow or tubular filaments of cellulose esters and regenerated cellulose be made by variations in the spinning conditions. Such hollow filaments of the prior art have numerous disadvantages, e. g., they have extremely low tensile strength, undergo considerable collapse during processing or use so that the advantages of the voids are partially lost, and are subject to the tendency of water or dry-cleaning fluids to enter and to be retained in the hollow filaments.

It has also been proposed to form porous filaments by incorporating gases or gas-forming materials in spinning solutions or by leaching from a filament a soluble additive that has been co-spun in the filament. However, the manufacture of such porous filaments have the disadvantages that the spinning processes are difficult to control and generally yield rough surfaced and non-uniform filaments due to bubbles or voids that open onto the surface of the filament.

An object of this invention is to provide smooth-surfaced, low density novel filaments particularly in a range of deniers suitable for textile purposes, having voids which are resistant to crushing and to the entrance of liquids into the voids. A further object is the production of yarns composed of a number of such filaments. Another object is to provide a process for the manufacture of such filaments and yarns. Other objects will appear hereinafter.

The objects of this invention have been obtained by the formation of filaments having a strong, smooth-surfaced, solid sheath of a fiber-forming, drawable, synthetic linear polymer completely surrounding a core in which the core material differs from the sheath material and has voids intermittent along the filament length. In these novel filaments, portions of the core material form transverse partitions having a length along the filament of from 0.2 to 10 times the average filament thickness (dimension across the filament perpendicular to the axis of the filament) which, together with the sheath, enclose intermittent voids in the core, which voids have an average transverse dimension i. e., dimension perpendicular to the axis of the filament, of from 50% to 100% of the average thickness of the core, e. g., the average core diameter for a round core, and an average length along the fiber axis of from 50% to 1500% of the average thickness of the core. The dimensions of the voids and partitions in the core can readily be determined by measurements on photomicrographs of the filaments. The invention may be carried out by simultaneously spinning a drawable fiber-forming polymer as a sheath and another substance having different drawing properties (which may also be drawable to some

extent) as a core of a composite filament, followed by drawing of the filament under such conditions that the core material is fractured or fissured by the drawing process while the sheath is oriented so as to increase tenacity.

The filaments of this invention are characterized, among other things, by resistance to collapse of the enclosed voids under the compressive forces normally encountered in the handling of textiles. The filaments can, in general, be collapsed with fracture of the voids only by the application of very heavy compressive forces, e. g., by rolling with heavy rollers on a non-yielding surface.

The composite filaments of this invention are also non-permeable, to a marked degree, to liquids which are not solvents for or swelling agents for the sheath polymer. Thus, they are highly impermeable to water or organic solvents used for the cleaning of clothing or other textile products.

The term "voids" as used in connection with this invention signifies enclosed spaces devoid of the core-forming material, whether or not the enclosed spaces contain a gas.

The term "smooth surfaced," as used herein, signifies a surface which, while not necessarily free from bulges or differences in diameter from section to section, is, however, essentially free from abruptly formed protuberances connoting a break-out of the core material through the sheath and essentially from holes or fractures formed for any other reason. "Essentially free" means that the surface is unbroken over an inch or more of filament except for possibly an insignificant amount, e. g., 10% or less and usually about 0% of the total surface. Inasmuch as the core material is enclosed, within the sheath, the continuity of sheath throughout the filament, characteristic of this invention, precludes roughness on the outside of the filament.

The terms "draw" and "drawing" as applied herein to filaments and yarn, signifies permanent elongation or stretch under the application of stress in the solid state; such permanent elongation is distinct from elongation under stress, which is substantially lost upon release of stress, such temporary elongation being an important characteristic of textile yarns even when completely drawn. "Cold-draw" and "cold-drawing" refer to the drawing which can be carried out on a filament or yarn at room temperature and also at other temperatures below the melting or softening point and without necessarily requiring the aid of softening or stretch promoting agents; this type of drawing is generally accompanied by a necking down of the filaments under the drawing stress, particularly in the case of linear condensation polymers, e. g., polyesters and polyamides.

Referring to the drawings:

Figure 1 is an axial longitudinal section of a spinneret assembly which can be used to make the composite filaments of this invention;

Figure 2 is a transverse cross-section of the apparatus of Figure 1 taken at 2—2 thereof and showing a plan of the front or bottom spinneret plate.

Figure 3 is a transverse cross-section taken at 3—3 of Figure 1 to show the plan of the top or back plate thereof.

Figures 4 to 10 inclusive are lengthwise views, on a greatly magnified scale, of filaments made in accordance with the invention. Figures 4, 5, 7, 8, 9 and 10 are photographs in which the solid portion of the core is shown in white and the voids of the core section are shown in black. Figure 6, on the other hand, is a hand-drawing which, for convenience, shows the core in black and the voids in white.

The filaments of this invention may be spun by the

use of any apparatus which will properly spin composite filaments from synthetic polymers. To facilitate a description of the process of this invention, the apparatus described and claimed in co-pending Kilian U. S. patent application Ser. No. 519,031, filed June 30, 1955 and shown in Figures 1-3 of the drawings herein, will be described hereinafter as a suitable apparatus for the carrying out of the invention. Details of this apparatus not contained in the present description and suitable for the spinning of multi-component filaments, will be found in said Kilian patent application Ser. No. 519,031, and are incorporated herein by reference.

With reference to Figure 1, front or bottom plate 1 with orifices 2 is recessed at the back about plateau-like protrusions 4. Each orifice consists of capillary 21 at the exit and larger counterbore 22 leading to the capillary from the plateau. Back or top plate 7 is sealed against and spaced from the front plate by gasket 6 and shim 16, the former being ring-shaped and located near the periphery of the opposing faces of the two plates and the latter being disc-shaped and located concentric with the two plates. Relatively unconstricted region 12 between the two plates is interrupted at intervals by constricted regions 15 between the opposing face of the back plate and plateaus 5 of the protrusions from the front plate. The back plate is partitioned on top by outer wall 19 and inner wall 29 into annular chamber 8 and central chamber 9. The annular chamber communicates with the constricted regions between the two plates through counterbored apertures 10, consisting of terminal capillary 23 and counterbore 24, and the central chamber communicates with the intervening relatively unconstricted region through holes 11. The two plates are retained in place by cap 18 threaded onto the end of the back plate. The upper part of the housing (not shown) receives suitable piping or other supply means for separate connection to the two chambers, which may constitute distribution or filtering spaces as desired. Pin 14 through cylindrical openings (opening 25 in the front plate and opening 26 in the back plate) near one edge of the plates ensures the desired alignment of the two plates.

Figure 2 shows the plan of the front plate. Appearing in this view are eight plateaus, each concentric with an extrusion orifice and uniformly spaced about a circle inside the outer gasket. Figure 3 shows the appearance of the back plate sectioned as indicated on Figure 1. Visible are the concentric outer and inner walls, the capillaries and counterbores of eight apertures spaced uniformly on a circle between the two walls, and four openings located within the central chamber defined by the inner wall.

Operation of the described apparatus in the practice of this invention is readily understood. Separate spinning materials are supplied to the inner chamber 9 and the outer chamber 8, respectively, of the back plate; the former, a drawable fiber-forming polymer flows from central chamber 9 through the openings 11 into the relatively unconstricted space between back and front plates, through the relatively constricted regions between the plateaus and the opposing plate face, and through the counterbores 22 and extrusion orifices 21 to form the sheath of a filament while the latter passes first through the apertures 24 and 23 in the back plate and directly into and through the aligned orifices 22 and capillaries 21 in the front plate to form the core of composite filaments.

The expression "inherent viscosity" as used in the examples is defined as:

$$\frac{1\eta\eta r}{c}$$

wherein c is the concentration in grams of the polymer in 100 ml. of the solvent, ηr is the symbol for relative viscosity which is the ratio of the flow time of the poly-

mer solution relative to the flow time of the solvent, and 1η is the logarithm to the base e . The viscosity measurements for calculating the inherent viscosity are made on $\frac{1}{2}\%$ solutions by weight at 25° C. Inherent viscosity is a measurement of the molecular weight of the polymer.

In some examples, the relative viscosity (ηr) is used as a measure of the molecular weight and when this value is used herein for poly(hexamethylene adipamide) and for poly(ethylene terephthalate), it is to be understood that measurements were made on the following solutions: 5.5 grams of a polyamide in 50 ml. of 90% formic acid at 25° C. or 2.15 grams of the polyester in 20 ml. of a $\frac{7}{10}$ mixture of trichlorophenol/phenol at 25° C.

In the examples the amount of elongation produced by drawing in relation to the original length is expressed as "percent draw." Thus, a 100% draw signifies that the drawn filament is twice as long as the original undrawn filament.

The following examples, in which (as well as elsewhere throughout the specification) parts, proportions and percentages are by weight unless otherwise indicated, are intended to illustrate this invention and in no manner to limit it. Throughout the examples and specification, tenacities and elongations are dry tenacities and elongations determined by standard known testing methods.

EXAMPLE I

Molten poly(ethylene terephthalate) polymers of relative viscosities 33 and 5 respectively were simultaneously spun through a 34-hole spinneret similar to that shown in Figures 1-3 as the sheaths and cores respectively of composite filaments. The spinning pumps were adjusted to give 50% (by volume) sheath material and 50% (by volume) core material; the polymers were then spun at 288° C. into air at 30° C. and the yarn wound up at 1000 yards per minute. Samples of the yarn were drawn 150% at room temperature to produce strong, low density filaments of about 3 to 4 denier per filament having irregular shaped voids in the center of the yarn separated by transverse portions of the lower molecular weight polyester, as shown in Figure 4. The filaments retained their round cross-section through the drawing process and did not collapse upon subsequent treatment such as washing, bleaching and dyeing simulating textile processing. The filaments were laundered and dry cleaned without retaining liquid in the voids after air drying.

The polyester used for the core was of such low molecular weight that filaments could not be spun from it. It is known that a minimum molecular weight is required for spinnability and that even a higher molecular weight is required for the commercial spinning of uniform, strong, drawable filaments. A relative viscosity of 10 for this polymer is considered to be the minimum for fiber-forming properties, with a relative viscosity of 22 or higher being required for commercial spinning.

EXAMPLE II

Poly(ethylene terephthalate) of relative viscosity 33 and a commercial sample of polystyrene having an inherent viscosity in benzene at 25° C. of 1.0 were simultaneously melt-spun with the pumps set to deliver the polyester and the polystyrene as a 77% (by volume) sheath and a 23% (by volume) core respectively of composite filaments using the apparatus and procedure of Example I. Molded bars of the polystyrene had an elongation at the break of 1.8% at room temperature. The resulting yarn was wet with water and drawn 250% at room temperature. The drawn filaments, of about 3 denier per filament, had a tenacity of 1.5 grams per denier, an elongation of 25% at the break, a low density, and a delustered appearance. The filament is shown in Figure 5. The filaments did not retain laundering or dry-cleaning solutions after conventional cleaning treatments.

EXAMPLE III

Poly(ethylene terephthalate) of relative viscosity 33 and a low molecular weight, high density (0.952 gram

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per cc.) polyethylene with a melt index of 470 (ASTM-D 1238) were simultaneously melt-spun as sheath and core respectively using the apparatus of Example I. The spinning pumps were adjusted to give 50% by volume each of the sheath and core components and the filaments were extruded at 285° C. to 290° C. into air at 30° C. at a wind-up speed of 800 yards per minute. When the yarns were drawn 200% in a wet state at 25° C., shiny, opaque, low density (1.09 grams per cc.), porous filaments were obtained as shown in Figure 6. The yarn had a tenacity of 1.7 grams per denier, an elongation at the break of 25%, and a total denier of 110 for the 34 filament bundle. When the yarn was drawn wet or dry 200% over a pin at 75° C., a lustrous, solid, transparent filament was obtained with a density of 1.15.

EXAMPLE IV

A copolymer of methyl methacrylate and ethyl acrylate (98.5/1.5 ratio by weight) was made with a molecular weight of 125,000, a melt index of 4 (ASTM-D 1238 modified for a 3800 gram load at 230° C.) and an elongation at the break (as measured on molded bars) of 4% to 9% at 23° C. Poly(ethylene terephthalate) of relative viscosity 33 and the aforesaid acrylic copolymer were simultaneously melt-spun as a 75% (by volume) sheath and 25% (by volume) core respectively of composite filaments using the apparatus of Example I. When the resulting yarns were drawn 100% at room temperature a strong yarn of low density was obtained having alternate sections of voids and the polyacrylic copolymer having edges perpendicular to the length of the filament completely surrounded by a sheath of the polyester. The filaments were highly resistant to crushing. When the as-spun filaments were drawn 350% over a 3/4 inch diameter pin at 98° C. and wound up at 100 yards per minute; the two transverse edges of the polyvinyl core segments had a double concave appearance similar to those shown in Figure 7. The latter yarn had a tenacity of about 3.6 grams per denier, an elongation at the break of 18%, and had a total denier of 70 for the 34-filament bundle. The yarn was resistant to crushing and retention of liquids upon dry cleaning or laundering.

EXAMPLE V

The acrylic copolymer in Example IV was replaced with the same volume of a low molecular weight commercial polystyrene having an inherent viscosity in benzene of 0.20 and composite filaments were melt-spun using otherwise the equipment, materials, and spinning conditions of Example IV. It was necessary to devolatilize the polystyrene prior to spinning by heating it for twenty hours at 115° C. at 0.5 mm. of mercury. The resulting yarn was drawn wet 300% over a 57° C. pin and wound up at 100 yards per minute to give light, strong, delustered filaments of 2.5 denier per filament that were resistant to crushing, having a tenacity of about 1.3 grams per denier and an elongation at the break of about 25%. The drawn filaments were similar to those shown in Figure 8. The density of the as-spun fiber was 1.30 as compared with 1.01 for the drawn yarn. A control yarn composed entirely of the sheath polymer had a density of 1.33 by the same method. Similar porous yarns were also made by drawing wet filaments 300% at room temperature. Monofilaments that were spun from the polystyrene could not be drawn and were so weak and brittle that tensile properties could not be determined.

EXAMPLE VI

Poly(hexamethylene adipamide) of relative viscosity 39 and molten sulfur were melt-spun as sheath and core respectively from the apparatus used in Example I. The polyamide and the sulfur were held in the apparatus for about ten minutes at 280° C. before the spin began. The composite yarn having 50% (by volume) sheath and 50% (by volume) core had a bright golden color and was translucent as spun. When this yarn was drawn 200% at room temperature solid filaments were obtained.

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Upon standing at room temperature for one-half the appearance of the as-spun yarn changed from a lustrous, bright golden color to an opaque yellow-tan color. When the opaque as-spun yarn was then drawn 200% at room temperature, low density, strong filaments of about 4 denier per filament having intermittent sections of sulfur and voids in the core were obtained similar to those shown in Figure 9.

The filaments with intermittent segments of sulfur in the core also displayed a small random variation in the diameter of the filament due to the necking down of the sheath polymer over the voids produced during the 200% draw. The filaments of Example II (Figure 5) having a 23% to 36% (by volume) core after drawing 250% and those of Example V (Figure 8) having 53% to 62% (by volume) core after having 300% also showed this effect; (the core percentages referred to in this sentence are measured on filament sections containing only solid core surrounded by sheath). The amount of necking down over the voids will generally increase with the draw ratio used and with the length of the voids, and will also increase, for a given draw ratio, as the volume percent of the core of the as-spun filament is increased. This invention thus affords a filament with random, short-range variations in denier that can be readily controlled by this process but which is very difficult to make by old methods in the art.

EXAMPLE VII

Poly(hexamethylene adipamide) of relative viscosity 41 and poly(ethylene terephthalate) of relative viscosity 19 were melt-spun as the sheaths and cores respectively of composite filaments using procedure and equipments similar to Example I which was modified as described in the aforesaid co-pending Kilian Ser. No. 519,031, so as to locate the two components in an eccentric position, i. e., the round core non-symmetrically positioned in the round sheath. The as-spun yarn was soaked in methylene chloride for fifteen minutes to embrittle the core, dried for fifteen minutes in a relaxed condition on a 150° C. hot plate, and then hand-drawn 200% at room temperature. Filaments with intermittent voids and fractured polyester core were obtained in which the thinner sheath necked down in drawing eccentrically of the core to give a filament similar to Figure 10.

Thus the use of an eccentrically located core affords a light, strong yarn with short range variations in thickness and with surface irregularities predominating along mainly one side of the filament.

The solid core of the filaments of this invention may be any material that fractures or fissures upon drawing under conditions such that the sheath component draws without fracturing or fissuring. Thus the solid core material, even though it may be drawable to some extent, must draw a sufficiently less degree than the sheath material to fracture during the drawing of the composite filament. Preferably, however, the solid core will not draw over 20%. Also, it is preferred that the solid core have a maximum stretch at break not more than 10% of the maximum drawability of the sheath material under the conditions at which drawing is imposed to fracture the core; generally this ratio of drawability of core to sheath will be measured at the temperature at which draw is normally imposed on the sheath material, since the drawability of the core is ordinarily referred to drawing as practiced by the art. In addition, it is preferred that the solid core material be stable under the conditions of spinning. High temperatures such as may be employed in melt-spinning can in some cases cause depolymerization or decomposition of a polymeric substance. A slight amount of monomer or other volatile by-products from such depolymerization or degradation is permissible but an excessive amount can cause the formation of large bubbles with the possible rupture of the filament sheath and discontinuity of spinning. The viscosity of the melt of the normally solid core component (or its solution) if

wet or dry spun) should be sufficiently high so that it can be pumped and spun. However, since a core material is protected by the sheath, materials which are considered to be non-spinnable by themselves can be spun as solid cores of the sheath-core filaments of this invention.

By way of providing specific data as to the character of voids contained in the filaments of the above examples, the following table lists the characteristics of the drawn filaments of Examples I to VII inclusive particularly with respect to the solid core and voids.

Table I
DIMENSIONS OF DRAWN FILAMENTS

Figure	Example	Percent area of solid core in cross section	Void length		Void diameter
			solid core diameter	solid core diameter	
4.....	I	65	1.6		.5-.9
5.....	II	23, 26	1.5-4.5		1.0
6.....	III	50	4		0.5-.9
7.....	IV	32	1-10		1.0
8.....	V	57, 62	1-6		1.0
9.....	VI	50	0.7-1.5		1.0
10.....	VII	50	4-6		0.5-1.0

The filaments of the above examples may vary, in the case of some filaments, from the above figures which must therefore be considered as typical of the average filaments. In any event, the voids will have their largest transverse dimension at least 50% of that of the solid core and in many cases 100% or close to 100% of the transverse core dimension, i. e., complete or nearly complete fracture of the core as in Figures 5, 7, 8, 9 and 10 of the drawings as distinct from the fissured type of fracture illustrated in Figures 4 and 6.

Although this invention comprehends all manner of sheath-core filaments having discontinuous voids in the core segment, the filaments can be considered as falling into three classes: (1) Filaments having sharply fractured segments of core materials separating the voids. (2) Filaments in which relatively large fissures in the core material provide the voids. (3) Filaments with structures intermediate between (1) and (2).

Materials that are brittle at the drawing temperature of a composite filament and have relatively poor adhesion for the sheath polymer will serve generally as the clearly fractured type of intermittent core. Such materials are characterized by having relatively low elongations at the break and ultimate tenacities lower than the sheath material. Such materials may be amorphous, i. e., non-crystallizable as polystyrene or polyalkyl methacrylates, or they may be weak, crystalline materials such as sulfur or a low molecular weight polymer such as poly(ethylene terephthalate). Since crystallization of linear, high molecular weight polymers, such as might be used for the sheath, usually increases the difficulty of drawing, the core material should be preferentially crystallized in this latter case. If the core has a lower apparent minimum crystallization temperature (T_1) than the sheath polymer, the core can be preferentially crystallized by heating the yarn above the T_1 of the core but below the T_1 of the sheath, preferably in a taut condition. A convenient method for determining T_1 is described in the literature, e. g., in U. S. Patent 2,578,899. A low molecular weight poly(ethylene terephthalate) of relative viscosity 5 can be preferentially crystallized within a sheath of poly(hexamethylene adipamide) of relative viscosity 33 and a filament produced with a broken core by drawing after the crystallization step. The presence of plasticizers generally lowers the T_1 of the polymer so that if a plasticizer is used in the core, the T_1 of the core material is thereby lowered. Another means of crystallization that can be used if the T_1 of the two components are not sufficiently far apart for adequate thermal crystallization, is by using certain polar organic liquids

which are latent solvents for the amorphous regions of the core and thereby promote crystallization of the core without substantially affecting the polymer of the sheath. Acetone and methylene chloride have proven to be excellent materials to promote the crystallization of poly(ethylene terephthalate).

Non-brittle materials of low tensile strength and low elongation will afford a fissured core such as is shown in Figure 4. In general, non-brittle, low molecular weight polymers which are fiber-forming at higher molecular weights fulfill these requirements. The exact values of molecular weights of polymers to be used as a core will vary from polymer to polymer, but they will preferably be at or below the level considered as borderline for filament formation. For many polymers this means an average molecular weight of less than 10,000 as contrasted with values of from 15,000 to 50,000 and higher commonly used for commercial fibers. Any of the polymers listed below for sheath components can be used at sufficiently low molecular weights and preferably, in a non-crystalline form, as the core.

For the sheath of the filaments of this invention any fiber-forming polymer that can be spun into drawable filaments can be used, such as polyesters, polyamides, polyethers, polyacetals, polyurethanes, polyureas, polyhydrocarbons such as polyethylene, etc., and such polyvinyl polymers as polyacrylonitrile, polyvinylchloride, polyvinylidene chloride, and their copolymers. The sheath material is preferably a polymer capable of being drawn, with orientation, to yield strong, unitary (non-void containing) filaments, particularly filaments having a tenacity of at least 3.0 grams per denier.

Although the process of this invention has been illustrated with melt spinning, the desired two-component filaments can be plasticized—melt-spun as described in U. S. Patent 2,706,674 issued to Rothrock on April 19, 1955, or spun wet or dry from solutions of the filament components.

The amount of draw or stretch (permanent elongation) to be given to the filaments of this invention will depend upon the physical properties desired in the drawn fiber and the particular polymer used for the sheath. The elongation in the draw may range from 50% to 5000% depending on the drawability of the spun filaments. Drawing of from 100% to 600% are preferred.

It is preferred, as stated above, that the sheath polymer of the filament be capable of being drawn at least 100%, this drawing potential being characteristic of synthetic linear fiber-forming polymers. Fiber-forming polymers which can be cold-drawn, e. g., the linear condensation polymers such as polyamides and polyesters, as generally evidenced by the property of necking-down during drawing are the preferred sheath-forming material, not only because of their commercial availability, ease of processing and drawing, good properties and high drawing potential, but also because they can be melt-spun and are capable of wide and varied effects in the filaments. Melt-spinnable polymers are much preferred because of ease of spinning with a predetermined filament contour free of the complications involved where solvent must be removed with consequent irregularities of sheath and core in the solidified filament; melt-spinning of the sheath permits great flexibility in the spinning conditions and in the choice of sheath and core materials. Melt-spinnable polyesters, polyamides and polyesteramides preferred in the practice of this invention are described in U. S. Patents Nos. 2,071,250, 2,071,251, 2,071,253, 2,130,523, 2,130,948, 2,190,770 and 2,465,319.

One characteristic of the filaments of this invention is the sharp line of demarcation between the boundary between the sheath and core. This is possible because the shaped sheath and core materials meet close to the spinning orifice, and hence the streams have little opportunity to mingle with each other.

Any convenient drawing temperature can be employed

according to the drawability of the two component filaments. Thus the drawing temperature could range from below room temperature to just below the melting point or decomposition point of the sheath material. In general, temperatures of from 20° to 100° C. are preferred.

The length of the fractured core segments can be controlled and made more uniform by passing the yarn over a sharp edge, for example, a 90 degree turn over a small diameter wire and then drawing the yarn to the desired extent. Alternatively, a non-round drawing pin can be used, for example, a rod which is tear (droplet) shaped in cross-section on which the yarn is fractured and drawn in a single operation. It may be desirable to give the yarn a preliminary drawing short of fracturing the core in order to increase the strength of the sheath material so as to adapt it to the final drawing operation particularly where a sharp edge is used in the final drawing. Many other variations in the process of this invention will be apparent to those skilled in the art.

The sheath component of the drawn filaments of this invention may comprise from 10% to 90% of the solid core-containing filament cross-sectional area; for greater strength and lower density, filaments having a sheath of 20% to 80% of the solid core-containing cross-sectional area are preferred.

Although the invention may be applied to the production of filaments throughout a wide range of denier, it is preferred, since the invention is particularly applicable to the textile arts, to practice the invention for the production of filaments which in their drawn state have a denier of 1 to 10 inclusive and, for most purposes 1-3 denier, since these are the ranges most applicable to textile use.

The filaments of this invention are useful in all manner of textile applications. The filaments, which are of low density due to the voids they contain, lend themselves to use in light weight fabrics with good heat insulating and good covering properties. Furthermore, since the voids are non-continuous and disconnected, the filaments are highly resistant to the entrance and retention of cleaning fluid or other laundry liquids. Some species of the filaments of this invention have a short range variation in outer diameter which offers unusual and novel effects to fabrics constructed of such filaments. The process is of further advantage in that it offers a means of readily obtaining multi-filament yarns in a step-wise or, alternatively, in continuous process as desired.

Inasmuch as the invention is susceptible of considerable variation, any departure from the above description which conforms to the spirit of the invention is also intended to be included within the scope of the claims.

I claim as my invention:

1. A composite filament comprising, as one component, a sheath of fiber-forming polymer, and, as a second component, a core having less extensibility than said fiber-forming polymer, said core being formed in sections within the sheath and having voids formed between said core sections, said core and said voids being enclosed by said sheath whereby to impart to said sheath a smooth exterior.

2. A composite filament comprising, as one component, a sheath of fiber-forming polymer, and, as a second component, a core having less extensibility than said fiber-forming polymer, said core being formed in sections within the sheath and having voids formed between said core sections, said core and said voids being enclosed by said sheath whereby to impart to said sheath a smooth exterior, said voids having a length of at least 50% of the average core thickness.

3. A composite filament comprising, as one component, a sheath of fiber-forming polymer, and, as a second component, a core having less extensibility than said fiber-forming polymer, said core being formed in sections within the sheath and having voids formed between said core sections, said core and said voids being enclosed

by said sheath whereby to impart to said sheath a smooth exterior, said voids having an average transverse dimension at least 50% of the average core thickness.

4. A composite filament comprising, as one component, a sheath of fusible fiber-forming polymer, and, as a second component, a fusible core having less extensibility than said fiber-forming polymer, said core being formed in sections within the sheath and having voids formed between said core sections, said core and said voids being enclosed by said sheath whereby to impart to said sheath a smooth exterior.

5. A composite filament comprising, as one component, an oriented sheath of cold-drawable fiber-forming polymer, and, as a second component, a fusible core having less extensibility than said fiber-forming polymer, said core being formed in sections within the sheath and having voids formed between said core sections, said core and said voids being enclosed by said sheath whereby to impart to said sheath a smooth exterior.

6. A composite filament comprising, as one component, an oriented sheath of cold-drawable fiber-forming polymer, and, as a second component, a fusible core of polymer having less extensibility than said fiber-forming polymer, said core being formed in sections within the sheath and having voids formed between said core sections, said core and said voids being enclosed by said sheath whereby to impart to said sheath a smooth exterior, at least one of said components being a polyamide.

7. A composite filament comprising, as one component, a sheath of cold-drawable fiber forming polymer, and, as a second component, a fusible core of polymer having less extensibility than said fiber-forming polymer, said core being formed in sections within the sheath and having voids formed between said core sections, said core and said voids being enclosed by said sheath whereby to impart to said sheath a smooth exterior, at least one of said components being a polyester.

8. A composite filament comprising, as one component, a sheath of fiber-forming polymer capable of being drawn at least 50%, and, as a second component, a core having an extensibility not over 10% of the sheath drawability.

9. A composite filament comprising, as one component, a sheath of fiber-forming polymer capable of being drawn at least 100%, and, as a second component, a core having an extensibility not over 20%.

10. A composite filament comprising, as one component, a sheath of cold-drawable fiber-forming polymer capable of being drawn at least 100%, and, as a second component, a fusible core having an extensibility considerably less than said fiber-forming polymer.

11. The process which comprises forming a composite filament having a sheath of a drawable fiber-forming component and a core component drawable to a less degree than said fiber-forming component, then subjecting the filament to drawing sufficient to orient the sheath component while fracturing the core component.

12. The process which comprises spinning a molten fiber-forming drawable polymer as a sheath around a co-spun molten material as a core having less extensibility than the sheath material, solidifying said materials as a composite filament, then subjecting the filament to drawing sufficient to orient the sheath component while fracturing the core component.

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