June 2, 1964 R. B. HAYDEN 3,135,646

HELICALLY CRIMPED TEXTILE FILAMENTS

Filed May 5, 1961

FIG. 1

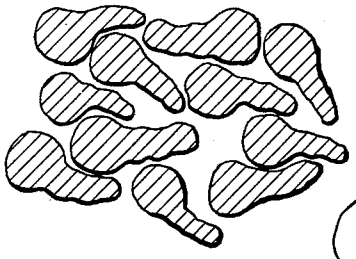


FIG. 3

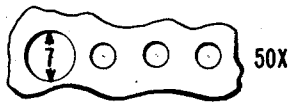


FIG. 2

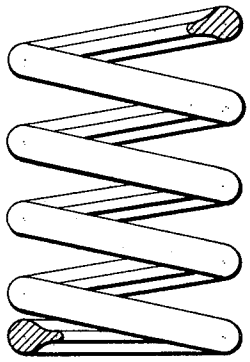


FIG. 4

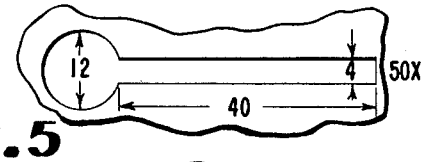


FIG. 5

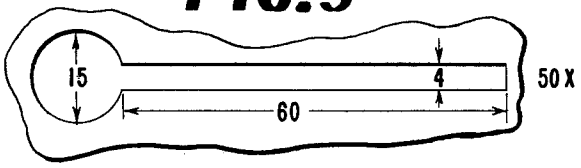


FIG. 6

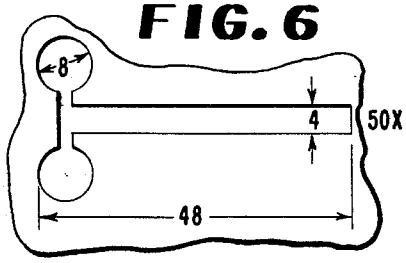


FIG. 7

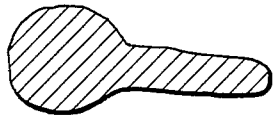


FIG. 8

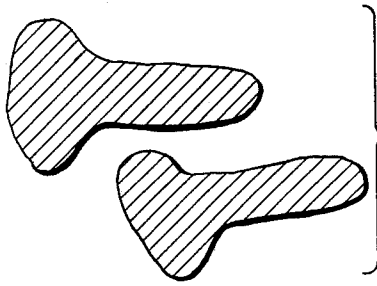


FIG. 9

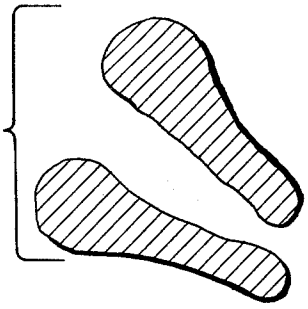
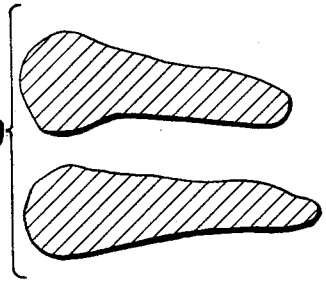


FIG. 10



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HELICALLY CRIMPED TEXTILE FILAMENTS

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6 Claims. (Cl. 161—173)

This invention relates to novel synthetic fibers and particularly to synthetic fibers having a novel structure which imparts high bulk to yarns composed of such fibers.

This application is a continuation-in-part of U.S. application Serial No. 334,457, filed February 2, 1953, now abandoned.

Investigators in the textile field have long been concerned with obtaining voluminous strands of continuous filaments with properties similar to those yarns obtained from natural staple fibers. Production of staple fiber yarn (also called "spun yarn") is quite expensive and requires a complex series of operations involving aligning the fibers, combining them into an elongated band and drawing the bundle to smaller diameter while twisting to prevent excessive slippage of adjacent fibers past each other, together with still further operations required to produce a yarn or thread useful for textile purposes.

Synthetic fibers are produced directly as continuous filaments by an extrusion-spinning process. Strands or yarn can be made merely by combining the continuous filaments and without the time-consuming and expensive processing steps required for the making of spun yarn from staple fibers. The continuous filament yarn can be made very strong because of the absence of loose ends found in staple yarn that are unable to transmit imposed stresses. However, due to their lack of loose ends and their cross-sectional and longitudinal uniformity, conventional continuous filament yarns are more compact and dense than their staple counterparts since the continuous filaments lie close together in the yarn. This compactness, when the yarns are made into fabric, e.g., woven or knitted fabric, limits the amount of insulating air space present, reduces the visual covering power of a given weight of fabric, and imparts to the fabric a hard, slick hand typical of synthetic continuous filaments.

Bulky continuous filament yarns have been made by heat-setting a highly twisted yarn of, for example, nylon, at least partially untwisting the yarn with, if necessary, further twist in the opposite direction and then plying two ends of opposite twists. Such a process is very expensive and, while affording a voluminous yarn, is too elastic for many textile applications.

It has also been proposed to make a voluminous continuous filament yarn by mechanically crimping the yarn, for example, by a hot stuffing box process. Such a product, while more voluminous than uncrimped continuous filament yarn, has the disadvantage that it must be fabricated in the bulky form, and the further drawback that it loses an appreciable amount of its bulk due to the crimp being pulled out by the tensions encountered in fabric formation.

It is an object of this invention to provide novel helically crimped filaments. A more specific object of this invention is to provide a helically crimped filament which has a bulbous cross section which is particularly useful in preparing bulky yarns. These and other objects will become apparent from the detailed description which follows.

The objects of this invention are accomplished by the preparation of a helically crimped polyamide textile filament having a bulbous or keyhole shaped cross section comprised of a stem portion and a fin projecting therefrom. The fin is oriented toward the axis of the helix. The cross section of the filament has a length to average

width ratio (hereinafter designated L/W) of at least 2.0:1, preferably in the range from 3.0:1 to 5.0:1, and an area ratio of at least 1.5:1.

By the length of a cross section is meant the length of the longest line that can be drawn with the perimeter of the cross section such that each point on the line is equidistant from the perimeters on both sides of the line. By the average width of the cross section is meant the ratio of the cross-sectional area to the length of the cross section.

By the expression "bulbous" is meant that the two halves of the cross sections defined by a line perpendicular to the length of the cross section at its midpoint have areas with a ratio of 1.5:1 or greater. Preferably the area ratio is in the range from 1.5:1 to 3.0:1.

Referring now to the drawings:

FIGURE 1 is a reproduction of a photomicrograph showing the cross sections of a bundle of filaments of this invention;

FIGURE 2 is a representation of one filament of the present invention illustrating the helical crimp and orientation of the fin toward the axis of the helix;

FIGURES 3 through 6 represent spinneret orifices of various sizes and shapes, with dimensions in mils, which are useful in the production of the filaments of the present invention; and

FIGURES 7 through 10 are enlarged representations of the cross sections of other filaments of the present invention.

In preparing the filaments of this invention spinning, quenching, and drawing conditions may be controlled as will be described in the examples which follow later herein. In general, the filaments are prepared by extruding a molten polyamide through orifices of the type shown in FIGURES 3 through 6. The filaments are rapidly quenched, and thereafter the quenched filaments may be drawn or attenuated in one or more steps. Preferably a polymer having a high molecular weight such as that which corresponds to a relative viscosity of 45 or higher for 66 nylon and a low moisture content, e.g., 0.15% or less, is selected. The filaments may be quenched in water or cooled air containing moisture.

Filaments of all textile deniers may be prepared according to the present invention. Since the helical crimp of the filaments displays reversal points at frequent and random intervals, and the frequency is an inverse function of the denier, deniers in the range from 1 to 30 are preferred.

The products of this invention are fairly elastic due to the 10 to 80 or more helical crimps per inch of crimped length. They have a crimp index of 20 to 100 or more and preferably 40 to 100 or more.

Crimp index, which is a measure of the extent of crimp found in a filament, is measured by the following procedure. A skein of approximately 6000 total denier is made up of the yarn, placed in a stainless steel strainer and immersed in boiling water for thirty seconds. Following this, the skein is blotted and hung up to air dry. After drying, the skein is suspended adjacent to a meter stick and loaded with 0.0227 gram per denier. The loaded length is observed. The load is then removed, and, after a waiting period of thirty seconds, the retracted length is observed. Crimp index is equal to the change in length due to retraction expressed as a percentage of the total loaded length.

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

$$\frac{\ln(n)_r}{c}$$

wherein c is concentration in grams of the polymer in 100 ml. of the solvent, $(n)_r$ is the relative viscosity which

is a ratio of the flow time in a polymer solution and in the solvent alone, and ln is the logarithm to the base *e*. The measurements are made on solutions containing 0.5 gram per 100 ml. of solvent.

Where the term "relative viscosity" is used alone, it refers to the $(n)_r$ value as measured on a solution of 5.5 grams of the polymer in 50 ml. of 90% formic acid at 25° C.

The folowing examples, in which parts and percentages are by weight unless otherwise specified, further illustrate the present invention.

Example I

A monofilament spinneret is constructed by drilling orifices in the patterned arrangement illustrated in FIG. 3. The large hole has a diameter of 0.007 inch. The three smaller holes have diameters of 0.004 inch. They are spaced 0.008 inch from center-to-center. The spinneret is locked in conventional, melt-spinning equipment. A flume of water is located within one-half inch of the extrusion face. A hexamethylene adipamide polymer of relative viscosity 46 is extruded through the spinneret into the water flume. The filament is wound on a bobbin at a wind-up speed of 100 yards per minute. When unwound from the spin bobbin, the filament is observed to have a natural twist, forming a tight, spring-like coil. The helical crimp increases on boiling in water. The various filaments have a keyhole shaped cross section. A magnified, cross-sectional view of such filaments is illustrated in FIG. 1. They have a L/W ratio of 3.2 and the ratio of the areas of the two halves is 1.6.

When the polymer of the above example is spun into a standard air chimney, a filament with a bulbous or keyhole shaped cross section is formed. It is observed to have slightly less natural twist than when water is the quenching medium.

Example II

Poly(hexamethylene adipamide) with a relative viscosity of 45, containing 0.10% moisture was extruded through a spinneret at 270° to 275° C. The two-inch diameter spinneret contained thirteen keyhole-shaped orifices as shown in FIG. 4 comprising a 40 by 4 mils slot attached to a 12-mil diameter hole arranged on a one-inch diameter circle with all slots being parallel. The extruded filaments were quenched with a stream of refrigerated air at a rate of 136 cubic feet per minute (c.f.m.) (wet bulb/dry bulb of 44°/54° F.) perpendicular to the long dimension of the filaments coming from a screen-covered quenching chamber with an opening 9 inches wide by 12 inches long, the top of which was located 2 inches below the bottom of the spinneret. The distribution of quench air velocity was such as to give a peak linear velocity approximately 8 inches above the bottom of the quenching area. The extruded filaments were then passed through a pigtail guide, between a pair of cooled, matt-finished, tandem pin snubbers, over a skirted finish roll, then under and over two spaced feed rolls, and finally wound up at 800 yards per minute. The tandem pin snubbers were rotated to position the thread-line horizontally between them to provide a tension of approximately 0.14 gram per denier (based on windup denier) between the feed rolls, thereby drawing the filaments about 1.5 times their original length. An aqueous emulsion of mineral oil was applied to the filaments by the skirted finish roll.

The 330-denier yarn obtained had a tenacity of 0.63 gram per denier, an elongation of 83%, and an initial modulus of 2.3 before boil-off. Typical cross sections of the yarn are depicted in FIG. 7. They have a L/W ratio of 4.9 and the ratio of the areas of the two halves is 2.2:1. After boiling in water for one-half minute, the filaments developed a tight helical crimp (with the fins of the filament oriented toward the center of the coil) of 15 crimps per inch of crimped length and a crimp index of 44.

Similar results were obtained when a spinneret containing thirteen orifices as shown in FIG. 6 was used in the above example, and filaments with cross section corresponding to FIG. 8 with a similar high degree of helical crimp were obtained. These cross sections had a L/W ratio of 3.3 and the ratio of the areas of the two halves was 2.1:1.

The first yarn described above was converted to carpet yarn by plying 12 ends with producer twist only. A loop-constructed tufted carpet fabric with a 30 oz./yd.^{2} pile yarn takeup was made, and the filaments crimped by boiling fifteen minutes in water. The fabric had good bulk with a resilient pile and had a pleasing handle. The bulk and covering power of the fabric were equivalent to a control fabric made of yarns spun from mechanically crimped staple fibers. A control fabric made of mechanically crimped continuous filaments had poor bulk and a harsh, unpleasant handle.

Excellent carpets were also made from the above yarns that had been boiled off to develop crimp before carpet fabrication.

Example III

Poly(p-xylylene azelamide), made from para-xylylene diamine and azelaic acid, with an inherent viscosity of 0.9 and containing 0.07% moisture, was melted and extruded through a spinneret at 290° C. The spinneret contained 13 orifices as shown in FIG. 5 arranged on a one-inch circle with the long portions of the orifices all being parallel and oriented in the same direction. Room temperature air at a rate of 75 cubic feet per minute was used in the quenching device of Example II. The yarn was wound up at 210 yards per minute without any extra draw in the spinning afforded by the pin snubbers in Example II. The two ends of the yarn were drawn to a length of 2.25× their as-spun lengths (2.25× draw ratio) over a pin heated to 66° C. at a windup speed of 76 yards per minute. The drawn yarn had a total denier of 482 (26 filaments), a tenacity of 1.39 grams per denier, an elongation of 22%, and an initial modulus of 38 grams per denier. After boil-off, the yarn had a crimp index of 56.5 and contained 20 crimps per inch of crimped length. Typical cross sections of the drawn yarn are shown in FIG. 9. They had a L/W ratio of about 4.7 and the ratio of the areas of the two halves was 1.9.

Pile carpets made of the above uncrimped yarn displayed excellent properties after crimping the yarn by boiling off the fabric.

Example IV

Poly(hexamethylene adipamide) with a relative viscosity of 45 was extruded through a spinneret at 268° C. The two-inch diameter spinneret contained 15 keyhole-shaped orifices as shown in FIG. 4 comprising a 40 by 4 mil slot attached to a 12-mil diameter hole arranged on a one-inch diameter circle with all slots being parallel. Other spinning conditions were similar to those used in Example II, and the yarn was wound up at 1206 yards per minute. The 40-denier yarn had a tenacity of 1.15 grams per denier, an elongation of 52%, and an initial modulus of 8.1 grams per denier. After boiling in water, the yarn had a crimp index of 58 and contained 50–60 crimps per inch of crimped length. The filaments had cross sections similar to FIG. 7.

Tricot fabrics were prepared using above yarn before crimping as the top-bar component and a yarn of similar denier but of round cross section and uncrimped as a bottom bar. After boiling to develop bulk and crimp, the fabric had a very pleasing hand, was quite bulky and pleasantly soft, and had excellent covering power. A control tricot fabric knitted only of round cross-section nylon filament developed much less bulk, was lean in appearance, and did not have the pleasing, soft hand of the fabric made of filaments of this invention.

Among the suitable polyamides for use in this invention are those synthetic linear fiber-forming polyamides which are prepared from polymerizable monoamino monocar-

boxylic acids or their amide-forming derivatives, or from suitable diamines and suitable dicarboxylic acids or from amide-forming derivatives of these compounds. Typical of such polyamides are those formed from an aliphatic diamine and an aliphatic diacid containing the repeating unit

$$—X—Z—Y—Z—$$

wherein —X— and —Y— represent divalent aliphatic or cycloaliphatic groups and —Z— represents the

$$—\overset{\overset{O}{\|}}{C}—\overset{\overset{H}{|}}{N}—$$

linkage. Polyhexamethylene adipamide and caproamide (i.e., "66" and "6" nylons) are typical. Other suitable polyamides are those having the repeating structure

$$—A—Z—X—Z—$$

wherein —A— is a divalent aromatic radical and —X— and —Z— are as previously defined. Polyhexamethylene terephthalamide is illustrative of such polymers. Additionally, polyamides having repeating units such as

$$—A—Z—B—Z—$$

and

$$—X—Z—B—Z—$$

wherein —B— is divalent alkaryl (such as xylylene) may be used. Another class of suitable polyamides containing other than aromatic intracarbonamide repeating units are those prepared from piperazine, such as those from piperazine and adipic acid, piperazine and terephthalic acid, and the like. Copolyamides, condensation copolymers wherein the amide linkage is the predominant linkage, and polyamide mixtures are also useful.

Suitable high molecular weight polyamides and their preparation are illustrated in U.S. Patents 2,071,250, 2,071,253 and 2,130,948.

Particularly suitable polyamides include polyhexamethylene adipamide, poly(ε-aminocaproic) acid, poly(p-xylylene azelamide), and poly(m-xylylene adipamide).

The self-crimping filaments of this invention are of great

utility in that they offer bulk, covering power, and handle normally found with expensive spun staple yarns in continuous filament form which offer great economy in the fabrication of all types of fabrics such as knit wear and in the higher deniers as carpets. Fabrics made of the filaments of this invention do not fuzz and pill as do fabrics made of conventional, round cross-section filaments of the same polymers in a spun staple form.

As many widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that this invention is not to be limited to the specific embodiments thereof except as defined in the appended claims.

I claim:

1. A helically crimped polyamide textile filament containing at least 10 crimps per inch and having a denier from 1 to 30 and a bulbous cross section comprised of a stem portion with a fin projecting therefrom, said fin being oriented toward the axis of the helix, said cross section having a length to average width ratio of at least 2:1 and an area ratio of at least 1.5:1.

2. The filament of claim 1 wherein said length to average width ratio is in the range from 3.0:1 to 5.0:1.

3. The filament of claim 2 wherein said area ratio is in the range from 1.5:1 to 3.0:1.

4. The filament of claim 3 wherein said polyamide is poly(hexamethylene adipamide).

5. The filament of claim 3 wherein said filament has a crimp index of at least 40.

6. The filament of claim 5 wherein said filament contains from about 10 to 80 crimps per inch.

References Cited in the file of this patent

UNITED STATES PATENTS

2,002,153	Mendel	May 21, 1935
2,287,099	Hardy	June 23, 1942

FOREIGN PATENTS

741,739	Germany	Nov. 17, 1943