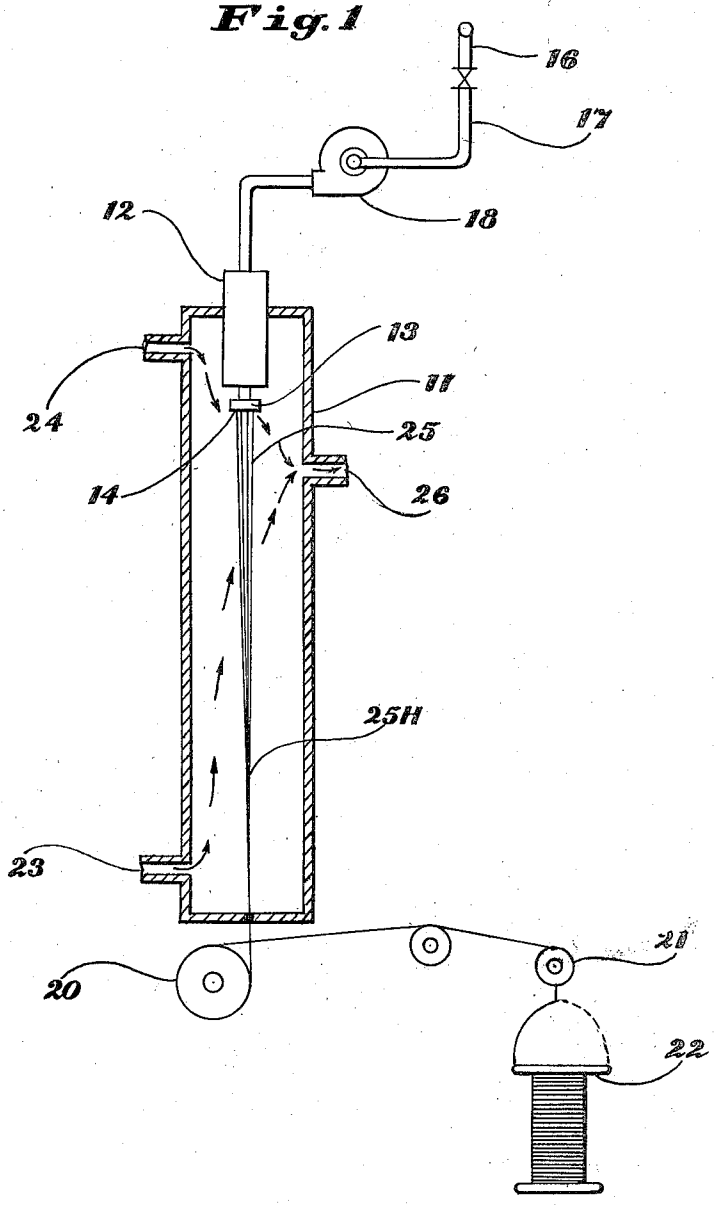
March 4, 1958 A. S. SMITH 2,825,120

SYNTHETIC FILAMENT

Filed May 11, 1954 2 Sheets-Sheet 1

Fig. 1



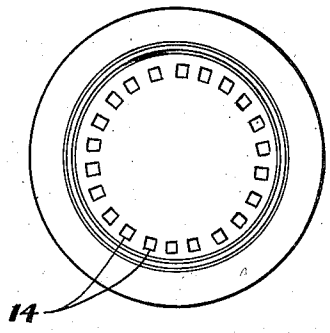
Arthur S. Smith
INVENTOR.
Daniel J. Wayne,
BY Walter O. Hodsdon
ATTORNEYS

March 4, 1958 A. S. SMITH 2,825,120

SYNTHETIC FILAMENT

Filed May 11, 1954 2 Sheets-Sheet 2

Fig. 2



SECTION OF SPINNERETTE SHOWING ONE ORIFICE

Fig. 3

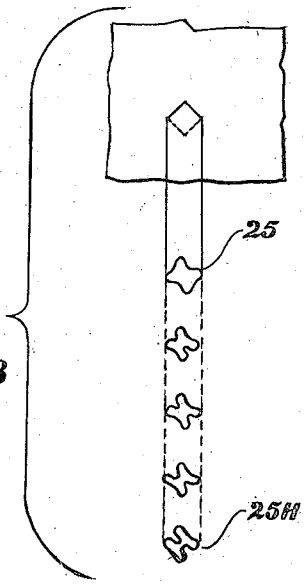


Fig. 4

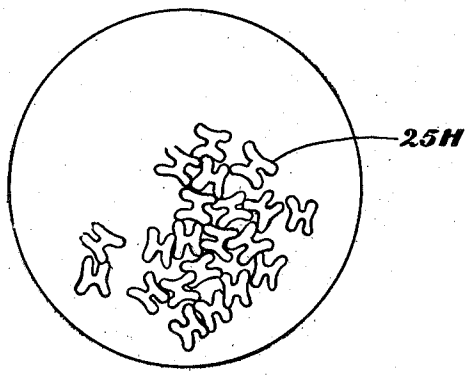
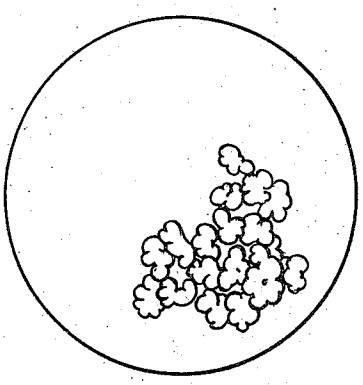


Fig. 5
PRIOR ART



Arthur S. Smith
INVENTOR.
Samuel I. Mayne
BY Walter O. Hodsdon
ATTORNEYS

United States Patent Office 2,825,120 Patented Mar. 4, 1958

2,825,120

SYNTHETIC FILAMENT

Arthur S. Smith, Kingsport, Tenn., assignor to Eastman Kodak Company, Rochester, N. Y., a corporation of New Jersey

Application May 11, 1954, Serial No. 428,890

2 Claims. (Cl. 28—82)

This invention relates to the preparation of synthetic filaments and fibers of increased luster, stiffness and increased bulk. More particularly this invention relates to improved dry spinning methods and apparatus for producing from cellulose ester spinning solutions filaments and fibers of an H-shaped cross-section having such desirable characteristics. Furthermore this invention also relates to fabrics and other articles of manufacture made of, or containing such H-shaped cross-section filaments and fibers.

Heretofore, various processes and apparatus have been provided for the production of synthetic filaments and fibers of various cross-sections. Generally these well-known cross-sections fall within one or two classifications such as relatively narrow and rectangular cross-sections, or round or round-like cross-sections which include filaments of round and flat sides, cloverleaf configurations and other related variations produced by physically deforming the filament, after it has assumed its normal shape, as it issues from the spinning cabinet.

Typical methods and apparatus for dry spinning solutions into synthetic fibers are disclosed in U. S. Patents 2,000,047 and 2,000,048 of May 7, 1935, to H. G. Stone. These patents describe methods including the forcing of a heated cellulose ester spinning solution through a spinnerette having a plurality of separated round orifices and into a drying chamber containing an evaporation atmosphere maintained at a suitable drying temperature. By such controlled conditions filaments can be consistently formed of approximately round or clover-leaf cross-section as contrasted to the filaments previously produced of elliptical shape.

Also, as shown in U. S. Patent 1,695,455 of December 18, 1928, by drawing the filaments from the round orifice spinnerette in a direction other than perpendicular to the horizontal face of the spinnerette, filaments having a more or less flattened cross-section are produced. It is also known that slight variations from the round cross-section can be caused by adjusting the particular evaporating conditions under which the filaments are dried in the spinning cabinet. A suitable selection of these conditions will permit the production, from spinnerettes having round orifices, of filaments with either a smooth or an unsymmetrical, irregular surface.

In U. S. Patent 1,773,969 of August 26, 1930, the technique of the extrusion of filament forming solutions through circular orifices into evaporative atmospheres is also discussed. As described therein it is suggested that the outer layer of the stream of cellulosic material which is initially circular in cross-section as it issues through the spinnerette orifices hardens or solidifies first forming a skin that is tougher and less fluid than the interior. After this initial hardening of the outer surface, the interior of the filament is precipitated or dried and thereby shrinks while the outer layer is further hardened. The outer shell of the filament being tougher and more determined in shape than the interior, the contraction of the volume of the interior causes the outer film or layer to collapse and to assume a very irregular cross-section which is in the form of a figure of many indentations of varying sizes and shapes and which is often quite flat. Because of the irregularity of shape and flatness of the cross-section of such filaments, their covering power, their

bulk, stiffness and luster are quite irregular. This Patent 1,773,969 then describes the use of spinnerettes having orifices of compact or squat shape having indentations in the form of re-entrant angles. The re-entrant angles can be constituted by straight or curved boundary lines. However, the filaments produced by extruding cellulose ester filament forming solutions through such orifices have more or less cross-sections characterized by rounded surfaces.

As described in Hickey Patent 2,373,892 of April 17, 1945, I-beam type cross-section filaments or fibers having a high degree of resiliency and crush resistance may be produced by extruding a suitable cellulose ester solution through a spinnerette having rectangular orifices, the ratio of the length to the width of each rectangular orifice being between 1.35 and 1.65. Fibers made from such I-beam filaments are particularly useful for manufacturing carpet materials, as well as, for the manufacture of rugging and other pile fabrics. However, the ends of the I-beam are of a round shape and do not extend substantially above the flat section of the I-beam.

An object, therefore, of the present invention is to provide a process for preparing filaments and fibers with an increased bulk and stiffness as compared to above discussed prior art fibers of equivalent denier and chemical composition.

Another object of this invention is to provide a process for preparing filaments and fibers of increased surface area as compared to the above discussed fibers known heretofore in this art.

Still another object of this invention is to provide synthetic filaments and fibers of H-shaped cross-section of the nature hereinafter described.

A further object of this invention is the preparation of the desired filaments and fibers from spinnerette orifices of a simplified design that can be easily and accurately manufactured.

Yet another object of this invention is to provide a spinnerette having extrusion orifices therein of square shapes.

Another object is to provide staple fibers made from a plurality of filaments having H-shaped cross-sections.

Again another object is to provide new and novel fabrics containing such H-shaped cross-section filaments or staple fibers.

Still another object is to provide a novel filling material of increased resistance to matting which is suitable to employ in pillows and the like.

Yet another object of this invention is to provide fibers adaptable for use in manufacturing cigarette filters.

Other objects will appear hereinafter.

In accordance with the present invention these and other objects may be attained by forcing a suitable spinning solution through a spinnerette having a plurality of square shaped filament forming orifices therein and drying the resulting filaments in a spinning cabinet under carefully controlled conditions of temperature while subjecting the filaments to predetermined drafting. The temperature of the solution and its rate of extrusion may also be controlled for optimum results.

Under the optimum conditions of solution temperature and composition, extrusion, drying and drafting, the wet filaments as they leave the square orifices temporarily assume a square cross-sectional shape. However, in accordance with my invention, by careful control of the extrusion rate, the drafting rate and drying temperatures, there will be a change in the filament cross-sections from square to an H-shaped cross-section. Under preferred ranges of operation, as suggested above, and as described in detail further on in this specification, the H-cross section will be substantially uniform for each of the simultaneously extruded filaments.

In general the spinnerette having the square orifices may be employed with any suitable spinning cabinet such as, for example, one of the general kind described herein. The H-shaped cross-section filaments, however, can be prepared in accordance with our invention within a satisfactory range of spinning, drafting and solution conditions as is described hereinafter.

Another interesting feature of my invention is the discovery that filaments produced in accordance with my invention through square orifices have a more perfect H-shaped cross-section than is obtainable when a spinnerette having H-shaped cross-section orifices is employed. In fact in the latter case the filaments generally fall within the above named prior art classifications and are of a distorted rounded configuration and of non-uniform cross-section. They exhibit few of the desirable properties possessed by my novel H-shaped cross-section filaments.

The increased stiffness of fibers made from H-shaped cross-section filaments as contrasted with fibers made of filaments of various round or round-like cross-sections heretofore known in this art appears due to the intermeshing of the extensions of the H of the individual filaments in the filament bundle so that each is reinforced by another adjacent filament.

The increased bulk of fibers made of H-shaped cross-section filaments depends on the resistance of the H-section filaments to compressive forces when formed into fibers or yarn.

The present invention will be further understood by reference to the following detailed description in which several examples of my invention are given and to the related drawings in which:

Figure 1 is a schematic elevational view, partly in section showing a spinnerette which has square filament forming orifices positioned in a suitable dry spinning cabinet which is equipped with suitable auxiliary apparatus;

Fig. 2 is a view of the face of a spinnerette showing a plurality of filament forming orifices of square shape;

Fig. 3 is a greatly enlarged representation of the spinning solution coming out of the square orifices of the spinnerette and forming into the H-shaped cross-section filaments;

Fig. 4 is a reproduction of an actual photomicrograph showing the cross-section of several H-shaped filaments of the present invention; and

Fig. 5 is a reproduction of an actual photomicrograph showing in cross-section several filaments made by employing a spinnerette having round orifices in accordance with a prior art method.

The similar parts in the several figures are identified by the same numerals.

Referring to Figure 1 there is shown schematically a side elevation view, partly in section, of a spinning cabinet **11** and its associated apparatus by which the novel H-shaped synthetic filaments and fibers of the instant invention may be manufactured. Mounted at the top of the cabinet is a candle filter unit **12** to which is

connected a spinnerette **13** which in accordance with this invention has a plurality of orifices **14** therein which are of square shape. The face of this novel type of spinnerette with the square orifices **14** therein is shown in the greatly enlarged view of Figure 2. The candle filter may be uniformly heated by means of heating coils, not shown, which are positioned so as to surround candle filter **12**, and through which coils may be circulated any appropriate heat exchange medium such as water maintained at the desired temperature.

Spinning solution of composition described hereinafter is supplied from conduit **16** through valve **17** to pump **18** which forces the solution at the desired rate to the candle filter unit **12**, thence to spinnerette **13** from which it is initially extruded through the square orifices **14** in the form of square filaments **25**.

The filaments **25** pass downwardly in the cabinet **11** while progressively losing solvent by evaporation until, in a substantially solidified and dried condition they leave the cabinet **11** and pass around godet roll **20**, which is positioned below the lower end of the spinning cabinet **11**, godet roll **20** is driven at a uniform speed by means, not shown, to give the desired draft to the filaments **25**. From godet roll **20** the filaments pass over the usual guide rolls **21** and are finally wound onto a bobbin **22** after an appropriate twist has been imparted thereto, by means not shown.

To facilitate drying of solvent from the filaments during their travel through the cabinet, heated air is supplied to the cabinet **11** by means of inlet conduits **23** and **24** positioned respectively adjacent the lower and upper ends thereof, the air passing through the cabinet and emerging through outlet conduit **26** positioned at a substantial distance below spinnerette **13**, as illustrated.

The change of the cross-section of the filaments while in the cabinet from an initial square cross-section shape to the desired H-cross section shape is schematically illustrated in Figure 3. As shown at **25** the filaments have just been formed by the square orifices and are substantially of a square cross-section. Further on, in the downward progress of the filaments under the controlled condition of drafting and drying, they have changed to the desired H-cross section filaments **25H** which are depicted greatly magnified in Figure 4. The various conditions of operation are described in more detail in the following paragraphs.

My process is described in further detail in the following examples.

EXAMPLE 1

A spinning solution consisting of 26.5% cellulose acetate, 1.25% titanium dioxide, based on the weight of the cellulose acetate, 1.75% water and the remainder being the solvent, acetone was spun into H-shaped cross-section filaments of 55 denier using the apparatus and its general operation as described above in connection with Figure 1. The spinnerette had 13 square orifices therein. The conditions of operation are shown in Table I where they are identified as No. 1.

Table I

No.	Denier per strand	Number filaments per strand	Extrusion speed, M/M	Candle filter temp. °C	Extrusion temp. °C	Top air flow C. F. M.	Bottom air flow C. F. M.	Top air inlet temp. °C	Bottom air inlet temp. °C	Dimension of one side of square spinnerette orifice	Draft
1	55	13	500	65	62	500	500	70	85	0.067	1.10
2	75	19	500	62	62	500	500	70	85	0.067	1.10
3	150	38	500	65	61	800	800	70	85	0.067	1.10
4	150	7	211	65	-------	500	500	60	90	0.155	1.22
5	55	36	500	58	-------	500	500	60	85	0.047	-------
6	75	49	500	58	-------	500	500	60	85	0.047	1.43
7	300	7	100	65	-------	1,500	1,500	60	90	0.220	1.08

In this table the air flow in cubic feet per minute is calculated for one hundered spinning cabinets. The figures under the spinnerette orifice column represent one side of the square. The extrusion speed in meters per minute represents the rate at which the spinning solution is forced out of the spinnerette. This, in cooperation with the draft rate enables the filaments to change from the initial square cross-section to the H-cross-section while drying.

Draft may be defined rather broadly as the ratio of the linear velocity of wind-up of the filaments to the linear velocity of extrusion of the spinning solution. More specifically, draft may be defined as the ratio of the linear velocity at which the filaments are wound onto and off the godet roll of a dry spinning cabinet to the calculated average linear velocity at which the quantity of spinning solution necessary to the formation of any one of the plurality of filaments comprising the bundle of filaments wound onto and off the godet roll is extruded through any one of the plurality of orifices in the spinnerette employed in the spinning operation, the velocities being expressed in the same units of distance per unit time. For example, if the filaments are wound up at the godet roll at the same linear velocity that the spinning solution is extruded from the spinnerette, the draft is 1.0, thus signifying that the linear speed of wind-up is 100% of the extrusion speed. Similarly, if the filaments are wound up or withdrawn from the cabinet at the godet roll at a linear speed 50% greater than the speed of extrusion, the draft is 1.5, and so on.

Other columns of Table I are more or less self explanatory when considered in connection with Figure 1 of the drawings and the related description.

EXAMPLE 2

The cellulose acetate spinning solution of Example 1 was spun into H-shaped cross-section filaments of 75 denier per strand using the apparatus and its general operation as previously described. The spinnerette had 19 square orifices. The conditions of operation are shown in Table I where they are identified as No. 2.

EXAMPLE 3

The cellulose acetate spinning solution of Example 1 was spun into H-shaped cross-section filaments of 150 denier per strand. The spinnerette had 38 square orifices. The above described spinning equipment was used with the operating conditions shown as No. 3 in Table I.

EXAMPLE 4

A different spinning solution consisting of 30.0% cellulose acetate, 1.75% water and the remainder being acetone solvent was spun into H-shaped cross-section filaments of 150 denier. The spinnerette had 7 square orifices. The above-described spinning equipment was used with the operating conditions shown as No. 4 in Table I.

EXAMPLE 5

Another spinning solution consisting of 26.5% cellulose acetate, 0.6% titanium dioxide pigment, based on the weight of the cellulose acetate, 1.75% water and the remainder being acetone solvent was spun into H-shaped cross-section filaments of 55 denier. The same spinning equipment was employed with the operating conditions shown as No. 5 in Table I.

EXAMPLE 6

A spinning solution of the composition shown in Example 5 was spun into H-shaped cross-section filaments of 75 denier. The same spinning equipment was employed with the operating conditions shown as No. 6 in Table I.

EXAMPLE 7

A spinning solution consisting of 26.5% cellulose acetate, 1.75% water, the remainder being acetone was spun into H-shaped cross-section filaments of 300 denier. The spinning equipment hereindescribed was employed using a spinnerette having 7 square orifices. Conditions of operation are shown as No. 7 in Table I.

I have found that uniformly H-shaped cross-section filaments can be prepared under a relatively wide range of spinning and dope conditions. A primary requisite for optimum H-shaped cross-section yarn is that the spinning draft should be above 1.0 and preferably above 1.2. However somewhat deformed H-shaped cross-section filaments may be obtained using lower spinning drafts of 0.7 to 1.0. But as indicated above for purposes of attaining uniformity of cross-section a draft above 1.0 is preferable.

The temperatures listed in Table I are temperatures used to produce a quality product with a particular cellulose ester-acetone solution. These temperatures are not too critical and may vary over a substantial range. Changes in cellulose esters and cellulose ester to acetone ratios may require some alterations or changes in these temperatures.

While particular emphasis has been made to preparing H-shaped cross-section filaments from cellulose acetate, my process will also operate satisfactorily with the single and mixed organic acid esters such as those containing 2 to 4 carbon atoms.

I have also found that my spinning process employing spinnerettes having square orifices operates very well over a range of deniers per filament of 1.5 to 43, although higher denier filaments can be satisfactorily made by our invention.

That the bulk of the H-shaped cross-section fiber, because of its particular cross-sectional shape and increased surface area, is greater than the clover-leaf or regular cross-section fiber of equivalent denier is shown clearly in the following Table II where comparisons of equivalent samples of regular and H-shaped cross-section yarn made from the same spinning compositions are set forth.

Table II

BULK TESTS ON REGULAR AND H-CROSS-SECTION CONTINUOUS FILAMENT YARNS

Yarn	Bulk factor	Specific volume cu. in./lb.	Percent difference
Regular 55/36/.3	155.2	32.7	13.4
H 55/36/.3	175.5	37.1	
Regular 150/38/.3	154.1	32.4	9.9
H 150/38/.3	168.5	35.6	
Regular 300/7/.3	158.0	33.2	14.7
H 300/7/.3	180.5	38.1	

In Table II the numerical expressions 55/13/.3 and the like represent continuous filament yarn in terms of total denier, filament count, and twist. For example, 55/13/.3 designates a continuous filament yarn having a total denier of 55 made up of 13 filaments and having 0.3 turn per inch of twist. The denier per filament of such a yarn is the total denier divided by the number of filaments. In this example 55 divided by 13 equals approximately 4 denier per filament.

The data in Table II are determined by a test which has been developed in which yarn is wound under a specified tension until it fills a spool of a known volume. The amount of yarn required to fill this volume is weighed. From this weight the "Bulk Factor" and "Specific Volume" are calculated. The "Bulk Factor" is calculated by the following formula:

(Volume of spool × density of fibers ÷ weight of yarn to fill spool) × 100 = bulk factor

This formula expresses the bulk as a percentage ratio of the space occupied by the yarn to the space which would be occupied by solid material from which the yarn is made.

The "Specific Volume" is determined by converting the weight of yarn on the spool to cubic inches per pound.

The column shown as "Percent Difference" expresses as a percentage, the percentage difference between the bulk factor, or the specific volume, in the regular and H-section yarn. It will be noted that in continuous filament yarn the H-shaped yarn has from 10 to 15% more bulk than regular yarn. This difference can be seen visually when comparing the skeins from which these data were obtained.

Similar data are shown in Table III relative to staple fiber yarn made from regular and H section fibers of the same cellulose ester composition.

Table III

BULK TESTS ON REGULAR AND H CROSS-SECTION STAPLE FIBERS

Yarn	Bulk factor	Specific volume cu. in./lb.	Percent difference
Regular 20/1, 2 D/F, 2"	282.0	59.2	20.0
H 20/1, 2 D/F, 2"	338.0	71.0	
Regular 20/1, 3 D/F, 2"	262.0	55.2	33.2
H 20/1, 3 D/F, 2"	348.0	73.5	
Regular 12/1, 5 D/F, 2"	267.5	56.3	20.4
H 12/1, 5 D/F, 2"	322.0	67.9	

In Table III the staple fiber yarns are designated by their cotton count and their ply. For example, 20/1 designates a staple fiber yarn made up of a single end, which is 20's cotton count. This table also shows the denier per filament (2 d./f.) etc. and the staple length of the fibers (2") etc., from which the staple yarns are spun. The bulk factor and specific volume are determined as described above in connection with Table II. It will be evident that with samples of yarn of the same composition, denier and length and varying only in cross-section, i. e. between regular and H section, that the H section staple has from 20.0 to 33.2 more bulk.

The luster of the H-shaped cross-section yarn is appreciably greater than that of the regular or clover-leaf cross-section of equivalent denier and composition. Luster is measured by means of a photo-electric cell. The filaments are wound in a parallel manner around a flat piece of cardboard or other similar flat surface. Light reflected off these panels to the photo-electric cell imparts a potential which is translated into a numerical luster level. On comparative tests the clover-leaf panel of filaments record 0.77 volt whereas the H cross-section filaments of the same denier record 0.80 volt.

EXAMPLE 8

Staple fibers made from H shaped cross-section cellulose acetate yarn were employed as a filling material in a pillow. Because of their bulk they were found to be satisfactory for this purpose. A similar sized pillow containing the same weight of cellulose acetate staple fibers of equivalent denier of regular cross-section evidenced less bulk and did not resist matting under pressure.

EXAMPLE 9

Cigarette filters were prepared from H-shaped cross-section cellulose acetate fibers. Their interesting bulk and stiffness properties permit the construction of filters of interesting design.

Yarn composed of H-section filaments is much stiffer and more resilient than yarn having normal or clover-leaf cross-sections. The effect on stiffness of cross sectional shape can be estimated by comparing moments of inertia of fibers having different shapes but the same cross sectional area. By this method it was determined that H-section filaments are approximately 48% stiffer than normal filaments of equal size. Furthermore, it was found that when a plurality of H-shaped filaments are collected in a bundle as in a yarn strand or in a batting a greatly increased resilience or stiffness is noted which is more than would be expected from the increase in stiffness of individual fibers. This effect is attributed to the interlocking or tongue and groove mingling of the legs of the H-filaments making up the mass of fibers. This interlocking of fibers causes much greater resistance to interfiber slippage than can be obtained in a bundle of normal filaments. Thus the aggregate stiffness of a bundle of H filaments is much greater than the sum of the stiffnesses of the individual fibers.

The inherent properties of cellulose acetate fibers of the H-shaped cross-section are such that they offer numerous desirable properties in both woven and knitted fabrics. In such fabrics as ninons, marquisettes, and voiles, the H-shaped section fibers produce fabrics having desirable crispness and stiffness which are usually obtained only by special processing techniques or by special finishing. In flat fabrics, such as taffetas, twills, and satins, the increased bulk of the H shaped fibers produce fabrics having greater cover and thickness for a given weight of material. On the other hand there is the possibility of using less material to produce fabrics of the same cover and thickness thereby decreasing the cost. Yarns having an H cross-section produce fabrics with less tendency for the yarns to slip resulting in higher seam strength. This characteristic is particularly important in certain fabrics, for example, satins and twills. Loom finished taffetas have a crisper feel when made from H-section yarns.

Knitted fabrics from yarns with H-shaped sections exhibit increased body and hand which make them more desirable for certain uses such as sport shirts, men's ties, and dress goods. Yarns spun from staple fibers of H-cross section exhibit increase in bulk and stiffness as do the filament yarns. In addition, fabrics from these yarns have a wool-like feel or hand. In all of the fabrics which have been produced from cellulose acetate fibers of the H-shaped cross-section fabric properties have been obtained which are desirable and which are not obtained in cellulose acetate fibers of regular cross-section.

I claim:

1. A cellulose organic acid ester filament having an H cross-section, the verticals of the H being substantially uniform and of a length substantially equal to the length of the horizontal of the H plus twice the width of a vertical.

2. A cellulose acetate filament having an H cross-section, the verticals of the H being substantially uniform and of a length substantially equal to the length of the horizontal of the H plus twice the width of a vertical.

References Cited in the file of this patent

UNITED STATES PATENTS

2,152,826	Spencer	Apr. 4, 1939
2,313,296	Lamesch	Mar. 9, 1943
2,373,892	Hickey	Apr. 17, 1945
2,434,533	Wurtzburger	Jan. 13, 1948
2,588,583	Small et al.	Mar. 11, 1952
2,588,584	Small	Mar. 11, 1952
2,673,368	Denyes	Mar. 30, 1954
2,677,184	Webb	May 4, 1954