

March 22, 1966

J. R. WHITE

3,242,035

FIBRILLATED PRODUCT

Filed Oct. 28, 1963

FIG. 1

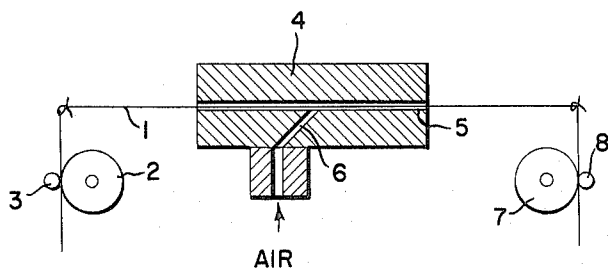


FIG. 2

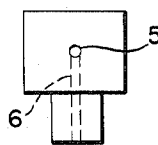


FIG. 3

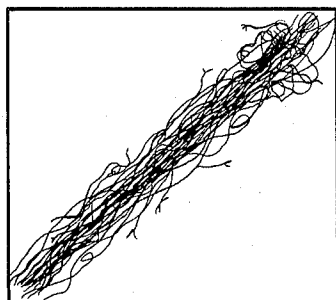
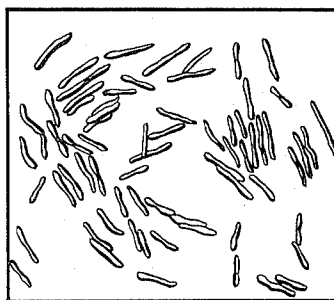


FIG. 4



INVENTOR
JAMES RUSHTON WHITE

BY

Ed Schwartz

ATTORNEY

3,242,035

FIBRILLATED PRODUCT

James Rushton White, Chapel Hill, N.C., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

Filed Oct. 28, 1963, Ser. No. 319,480

4 Claims. (Cl. 161-168)

This invention relates to a simplified process for preparing bulky yarns from synthetic polymers. More specifically, it relates to the preparation of bulky yarns directly from molecularly oriented film strips.

Artificial filamentary materials are usually produced as continuous filaments. Yarns made from these continuous filaments are much stronger than spun staple yarns, but lack many of the desirable aesthetic qualities of the spun yarns. Because of their uniformity and smooth surface, continuous filament yarns have less desirable tactile properties. The filaments lie close together in the yarn, and adjacent strands of continuous filament yarn in fabrics are closely spaced. This compactness makes for denser fabrics with less warmth and covering power per unit weight. Consequently, a large percentage of the total production of continuous filaments of synthetic material such as viscose rayon, cellulose acetate, nylon, poly(ethylene terephthalate), and poly(acrylonitrile) is cut into short lengths for spinning into staple yarns.

The production of yarn from staple fiber, both natural and synthetic, is a costly process. The conventional, widely used process involves a complex series of operations to align the fibers, combine them into an elongated bundle, and draw the bundle to smaller diameter while twisting to prevent excessive slipping of adjacent fibers past one another. These steps are necessary to secure adequate tenacity and uniformity. The cost and complexity of the process is markedly increased with the lighter denier yarns (e.g., cotton count greater than 30 cc.) used in making fine-textured wearing apparel fabrics. The higher cost is generally due to the necessity for obtaining greater uniformity of fibers in the smaller yarn bundle, the need for greater amounts of twist to secure adequate total yarn strength, and the fact that machine output is lower on a per-pound basis.

Although it has been known that yarn-like structures can be obtained by fibrillating highly oriented films, the products invariably obtained have been either too coarse or too weak to be useful without further treatment for the production of high quality textile fabrics. In general, a high degree of fibrillation is required to obtain the fineness of structure necessary for high covering power and pleasing tactile properties. However, when films are fibrillated to this extent by conventional methods they generally lack sufficient strength to be handled by conventional textile machinery in normal fabric producing operations, thus requiring that, following fibrillation of the film, some strength-imparting operation be carried out on the weak yarn. Typical strength-imparting steps such as twisting, as disclosed in U.S. 2,853,741, are expensive and are not needed to produce the yarns of this invention.

It is an object of this invention to provide a process for preparing bulky yarns from molecularly oriented film strips. It is a further object of this invention to provide a bulky yarn having the aesthetic qualities and covering power of staple spun yarns, but characterized by substantially high strength, even at zero twist. It is another object of this invention to provide fine denier, essentially untwisted bulky yarns having the covering power, aesthetic qualities and general utility of comparable denier spun staple yarns. Another object of this invention is to provide a continuous process for the production of strong bulky yarns without the extrusion of continuous filaments or formation of staple fibers as an intermediate step, and

without the necessity for spinning or twisting of filaments or yarns. Other objects and means for obtaining them will be apparent from the following disclosure.

In accordance with this invention, a molecularly oriented fibrillatable film strip of a synthetic organic high molecular weight crystalline polymeric material is passed through a zone of high turbulence provided by a high velocity jet or stream of air or other gas. Contact of successive portions of the film strip with the turbulent zone produces cohesive rupture of the film strip to form a multifibrous, continuous network of fibrils, and dislocates the fibrils into the configurations which characterize the yarns of this invention. The product thus obtained is a bulky multifibrous yarn made up of fibrils which are of irregular length and have a trapezoidal cross section wherein the thin dimension is essentially the thickness of the original film strip. The fibrils are interconnected at random points to form a cohesively unitary or one piece network structure, there being essentially very few separate and distinct fibrils existing in the yarn due to forces of adhesion or entanglement. However, a considerable number of fibrils are unattached on one end and protrude from the yarn bundle. The free ends are in most instances branched or flagellated.

Although the fibrils are in general coextensively oriented with the yarn axis, the dislocating force of the gas jet causes the fibrils to be interlaced, i.e., individually and collectively twisted, wrapped, intertwined and entangled. At random sites along the strand, the interlacing is so extensive that some fibrils wrap completely around the yarn bundle. The interlacing is quite stable due to the high frictional constraint between adjacent fibrils of trapezoidal cross section, and consolidates and strengthens the yarn bundle.

In addition to the interlaced configuration of the fibril network, a substantial number of the fibrils are convoluted into coils, loops, and whorls at random intervals along their length and at irregular spacings on different fibrils. The convolutions exist in fibrils in the outer or peripheral layers of the yarn bundle and also in fibrils within the yarn bundle.

The convolutions are tiny, complete loops formed by a fibril doubling back upon itself, crossing itself, and then proceeding in substantially the original direction. In mathematics a curve of this type is said to have a crunode. Accordingly, the characteristic loops will be more specifically defined as "crunodal loops," and loops of this type are intended, unless otherwise indicated in the following specification and claims. The majority of loops visible on the surface of the yarn are of a roughly circular shape and are properly described as "ring-like." The crunodal loops inside of the yarn are not readily studied, but it is evident that the pressure of surrounding fibrils would tend to cause such loops to assume more complex shapes. At least 10 crunodal loops can be detected per lineal inch of strand in preferred embodiments.

The invention will be better understood by reference to the drawings. FIGURE 1 is a schematic representation of a film strip passing through a jet device (in section) suitable for operating the process of this invention. FIGURE 2 shows an end view of the jet device of FIGURE 1. FIGURE 3 is a longitudinal schematic view of a unitary network yarn produced in accordance with this invention, showing fibril interlacing, flagellated free ends and crunodal loops. FIGURE 4 is a cross-sectional view of the yarn of FIGURE 3.

The flat cross-sectional configuration of the fibrils imparts remarkable stability to the interlacing and crunodal loops. Thus, the as-formed yarn of this invention, without having been twisted or subjected to any other process to alter the yarn structure, has a strong, coherent and

stabilized bulky structure. The untwisted yarns of this invention have a tenacity greater than 0.5 grams per denier and are eminently suited for direct use in the preparation of high quality fabrics by conventional textile machinery.

The yarns of this invention have a covering power greater than conventionally textured continuous-filament yarns of the same total denier and same number of individual filaments as fibrils. This may be attributable primarily to the flat or trapezoidal cross section, since geometrical considerations predict that a flat shape has more periphery than a round shape when both enclose the same area. Thus, per unit weight, the strands of the present invention have more surface area, hence more covering power, than comparable strands of the prior art. The improved covering power may be ascertained by tests in which the diameter of the projected profile of the yarn is measured microscopically. A 90-denier staple spun yarn with a 13-turns-per-inch Z-twist has a diameter of 5 mils, whereas a 90-denier, highly fibrillated yarn of the present invention, given 13-turns-per-inch Z-twist, has a diameter of 7 mils.

The yarns of this invention may be prepared in extremely small total deniers. Yarns of this invention can be prepared having cotton counts as high as 300. Spun yarns of this fineness are generally not obtainable from synthetic fibers. The yarns are sufficiently uniform to be handled easily by conventional machinery and to form highly uniform fabrics of good tactile properties without the sacrifice of bulk or fiber interlocking characteristics. They can be used without difficulty on both automatic weaving and automatic knitting machines. Increased covering effectiveness of fabrics made with this bulky product permits the production of fabric from smaller quantities of yarn. Because processing requirements for preparing films are not as stringent as those for preparing filaments, the yarns of this invention can be prepared from polymers which could not be readily converted into yarns by prior art processes.

Since yarns of the present invention have high strength even at zero twist, it is possible to retain bulkiness, even at low cotton counts, and to vary bulk independently of the cotton counts. It has been necessary in the past to introduce high twist in order to achieve high cotton counts.

If higher tenacities are required, the yarn of the present invention can be twisted. In this event, much lower twist is required for these yarns than is required to provide a comparable increase in the strength of staple spun yarns. The following table provides data comparing the effect of twist on the tenacity of the product of Example II, with the effect of adding twist to a conventional staple yarn. The strength of yarns from staple is substantially zero at zero twist, and no comparison can be provided below about five turns per inch.

TABLE 1

TWIST (turns per inch)	TENACITY (grams per denier)	
	Product of Example II	250-Denier Spun Yarn of Polyacrylonitrile 3-Inch, 3-Denier-Per-Filament Staple Fibers
0	1.3	0
5	2.2	0.01
10	2.5	0.71
20	3.3	1.0

The width of the fibrils, number of free fibril ends, crunodal loops and extent of interlacing are determined by the degree and type of turbulence employed in the fibrillation process and the nature of the film strip employed. The requisite turbulence necessary in producing the yarn product of this invention may be provided by a gas jet device similar to those shown in FIGURES 8, 9, 10 and 11 of U.S. 2,852,906, a simple embodiment

of which is shown in FIGURES 1 and 2. In FIGURE 1, film strip 1 is fed at a controlled rate by rollers 2 and 3 to jet device 4 and passed through cylindrical yarn passage-way 5. Intercepting this passage-way is gas entrance-way 6 with its axis preferably intercepting the axis of yarn passage-way 5. Rollers 7 and 8 remove the yarn at a controlled rate from the vicinity of the jet device. The axis of entrance-way 6 may be perpendicular to the axis of yarn passage-way 5 or may be inclined either forward or backward along the line of strand movement. Preferably, however, gas passage-way 6 will be inclined slightly forward, as shown in FIGURE 1, so that movement of the gas through the entrance-way serves to forward the strand through the jet and makes the device self-stringing. It is preferable that the strand, in passing through the jet device, be forced to change its path appreciably upon exiting from the air stream. For best results, the change in direction should amount to 30° or more (with the angle measured between emergent air stream and yarn take-off direction). In some instances, especially when increased amounts of interlacing are desired, it may be desirable to have the fluid entrance-way axis tangent to the strand passage-way channel so as to provide increased twisting action or torque upon the strand being processed.

One or another of the passage-ways in the apparatus, namely, yarn passage-way or gas entrance-way, may or may not be of uniform cross section or cylindrical in shape. In certain instances it may be desirable to have one or another of these passage-ways in the form of a right or oblique-conical section inverted or otherwise, and for some applications it may be desirable to have one or more of these passage-ways in the shape of a venturi or provided with a constricting orifice. Many adaptations of the apparatus designed to achieve a variety of results will be apparent, all being encompassed within the scope of the invention.

Preferably, air is utilized as the gas in carrying out the process of this invention, since this is the least expensive gas obtainable. Other gases, such as nitrogen, carbon dioxide, steam, oxygen, etc., may be used. The air pressure required to carry out this process depends upon the type of nozzle, the type of film, the film strip speed and the effect desired. Higher air pressures produce, with a given nozzle, higher turbulence in the zone contacting the film strip. Increased turbulence results in increased fibrillation, i.e., smaller fibril widths and greater numbers of free fibril ends. Although the products of this invention generally have an average fibril width between 4 and 100 microns and more than 10 free fibril ends per inch of yarn, conditions of high fibrillation produce average fibril widths between 4 and 50 microns and free fibril ends numbering more than 20 per inch. The more highly fibrillated yarns are generally preferred for their greater uniformity, covering power and softness. Although higher air pressures thus usually afford preferred products, the cost of compressing air makes it desirable to operate near the minimum pressure which will give adequate performance. Higher pressures are also required for higher strand speeds, but economics favor higher speeds because the air cost per pound of product drops off rapidly as the throughput is increased. In using the gas jet device, such as shown in FIGURE 1, gas pressures of 5 to 80 p.s.i. are employed. It is desirable that the air reach at least 1/2 sonic velocity as it enters the yarn passage-way. Preferably, the air speed at the point of contact with the film ribbon will be between 0.5 sonic velocity and sonic velocity. Excessive pressures produce weak or discontinuous products.

Fibrillatable films may be made from any polymer capable of possessing an appreciable amount of crystallinity and which will retain orientation on relaxation after stretching. Some of the many crystalline polymers that can be used include: vinylidene chloride polymers; isotactic polystyrene; high density polyethylene; isotactic

5

polypropylene; polyamides, such as poly(hexamethylene-adipamide), poly(ethylene sebacamide), poly(methylene bis-p-cyclohexyleneadipamide), polycaprolactam; polyesters, such as poly(ethylene terephthalate); and many others. Crystalline copolymers can also be used. Polyacrylonitrile and acrylonitrile copolymers with at least 85% acrylonitrile which appear to have only two-dimensional crystallinity (i.e., a high degree of lateral order as seen by X-ray diffraction) for the purpose of this invention are classified as crystalline polymers.

The polymers are formed by any suitable method into a film strip which may be either a ribbon, foil, tape, or thin hollow tube. They may be formed into wide films and then cut to the desired width. In order to obtain a film structure which is fibrillatable by the process of this invention to a continuous fibrillated bulky yarn, the film structures are drawn in the lengthwise direction to produce high unidirectional orientation. Fibrillating tendencies increase with increasing draw ratio and are most evident in highly oriented film strips of crystalline polymer. In order to afford fibrillated yarns of good uniformity and covering power by the process of this invention, it is essential that the thickness of the film strip material be below 15μ . However, for adequate yarn strength and usefulness, the thickness should not be less than 1μ .

The process of this invention is not limited to the formation of yarns from a single film strip. Two or more film strips may be used to build up a composite yarn of higher total denier from relatively thin film strips. Yarns of mixed composition may be formed by cofibrillation of film strips of different polymeric compositions. One particularly useful application is preparation of an antistatic yarn by cofibrillating with a single jet device film strips from polymers which develop opposite static charges. Similarly, one or more continuous-filament yarns may be subjected to the force of a single jet device together with one or more film strips. Heat treatments may be applied immediately before or during passage of the film strip through the jet to obtain heat-setting effects which may afford bulky, stretchy yarns with unusual hand or other novel properties.

The following examples illustrate specific embodiments of this invention. All parts and percentages are by weight unless otherwise indicated.

Example I

A linear polyethylene having a melt index of 0.2 is dissolved in decahydronaphthalene to produce a solution containing about 10% of the polymer. This solution is cast at 160°C . on a glass plate using a 5-mil doctor knife and dried at this temperature. The film strip obtained, which is approximately 0.5 mil thick and 0.87 inch wide, is drawn $12\times$ at 90°C . The resultant oriented film, which is approximately 0.1 mil thick and $\frac{1}{16}$ inch wide, is passed at approximately 30 feet per minute through the jet device shown in FIGURE 1 wherein yarn passage-way 5 is $\frac{1}{16}$ inch in diameter and $\frac{3}{4}$ inch long, fluid entrance-way 6 is $\frac{1}{8}$ inch in diameter and $\frac{3}{4}$ inch long and forms an angle of 30° with passage-way 5. The jet is operated with air at a pressure of 5 pounds per square inch. The product obtained is a 199 denier, multifibrous strand resembling a staple spun yarn and having a tenacity of 1.6 g.p.d. The yarn is a bulky, integral network of essentially longitudinally oriented random-length fibrils, having about 15 free, flagellated ends per inch of yarn. The fibrils have a trapezoidal cross section wherein the long dimension (or width) averages about 20 microns and the thickness is approximately 0.1 mil. About 15 crunodal loops can be distinguished per inch of yarn. The yarn contains extensive fibril interlacing and has a tenacity of 2 g.p.d.

Following the above procedure, but using an air pressure of about 60 pounds per square inch, a yarn is obtained having about 50 free ends and 50 crunodal loops

6

per inch of yarn, and a tenacity of 1.10 grams per denier at 0 turns per inch of twist.

Optimum processability is realized using air pressures of approximately 40 pounds per square inch. Individual fibrils of the yarns obtained under these conditions have average widths varying from 5 to 30 microns. When the pressure is increased to approximately 80 pounds per square inch, the fibrils have average widths varying from about 5 to 20 microns.

Example II

A 13% solution of polyacrylonitrile (inherent viscosity 1.4 in N,N-dimethylformamide) in N,N-dimethylformamide is cast at 95°C . on a sheet of glass using a 4 mil doctor knife. After the solvent is removed, a film about 0.25 inch wide and 0.00035 inch thick is obtained. This film is removed from the glass sheet and drawn $12\times$ over a hot plate at 130°C . to produce an oriented film approximately 2.5 microns thick and 0.07 inch wide. This film strip was passed through the jet of Example I using an air pressure of 5 lbs./sq. in. The product is a bulky, 51 denier yarn made up of interconnected, longitudinally oriented random length fibrils, each fibril being substantially trapezoidal in cross section wherein the long dimension averages 20 microns. There are about 20 loops per inch of yarn.

Following the same procedure as above but using an air pressure of 12.5 lbs./sq. in., a similar yarn is obtained having a tenacity of 1.3 grams per denier, about 40 loops and about 50 free ends per inch.

Optimum air pressure for processing the film of this example is about 20 lbs./sq. in. At higher pressures, greater flagellation of the fibrils accompanied by increased bulkiness is obtained at the expense of lower tenacities. At lower pressures there is less flagellation accompanied by less bulkiness.

Example III

A polyamide having an inherent viscosity of 1.35 in sulfuric acid and obtained by reacting m-phenylenediamine with isophthaloyl chloride is dissolved in N,N-dimethylacetamide containing a small amount of lithium chloride to obtain a solution containing 10% polymer. The solution is cast into a sheet at room temperature, using a 2 mil doctor knife, and the resulting film dried at 160°C . for 1 hour. The dried film sheet is drawn $5.5\times$ over a pin heated at 250°C ., and the resulting oriented film is approximately 0.1 mil thick. Strips approximately 0.25 inch wide are cut from this film and passed through the jet device of Example I at an air pressure of about 15 lbs./sq. in. There results a bulky yarn comprising a plurality of oriented anastomotic random length fibrils, each fibril being substantially trapezoidal in cross section. The bulky yarn has a denier of 55 (100 cc.) and a tenacity of 0.9 gram per denier.

Example IV

Polyethylene terephthalate having an inherent viscosity of 0.73 in a 60/40 mixture of tetrachloroethane and phenol is dissolved in trifluoroacetic acid to produce a 10% solution of polymer. This solution is cast into a film using a 2 mil doctor knife at 50°C ., and the film dried at this temperature. A $\frac{1}{8}$ inch strip of this film is drawn $5\times$ at 80°C . to produce an oriented film approximately 0.1 mil thick and $\frac{1}{16}$ inch wide. This oriented film strip is fibrillated (formed into fibrils) in accordance with the procedures of Examples I, II, and III by passing the strip through the jet device of Example I at air pressures varying from 5 to 80 lbs./sq. in. at 15 feet per minute. A bulky product was obtained with about 50 free ends/inch.

Example V

A polyurethane having an inherent viscosity of 1.5 in m-cresol and obtained by reaction of 25 dimethylpiper-

azine and the bis-chloroformate of ethylene glycol is admixed with a solvent containing 8.8 parts of methylene chloride and 12 parts formic acid. This admixture is in turn dissolved in a 95/5 methylene chloride/formic acid mixture to produce a 10% solution of polymer. After casting this solution into a film at room temperature using a 2 mil doctor knife, the resulting film is partially dried at room temperature and then more thoroughly dried by maintaining at 55° C. for 1 hour. The dried film is drawn 4.5× at 80° C. to produce an oriented film with a thickness of approximately 0.1 mil and a width of 60 mils. This film strip is passed through the jet device of Example I at a rate of about 15 feet per minute using an air pressure of 25 lbs./sq. in. The bulky yarn produced, which is similar in visual appearance to the bulky products of the previous examples, has a zero twist tenacity of 0.86 gram per denier, a denier of 130 and about 20 free ends per inch.

Example VI

A copolymer having an inherent viscosity of 1.4 in N,N-dimethylformamide and containing 94 parts of acrylonitrile and 6 parts of methyl acrylate is dissolved in N,N-dimethylformamide to produce a solution containing 25% polymer. This solution is extruded through a slot 0.5 inch wide and 0.004 inch high into an aqueous bath containing 52% by weight N,N-dimethylformamide at 75° C. After removal of the solvent, the resulting wet film is drawn 9× over a surface heated to 150° C. Fibrillation of the resulting oriented film is accomplished by passing a strip of the film approximately 0.2 mil thick and 80 mils wide through the jet device of Example I using an air pressure of 20 lbs./sq. in. A bulky yarn is obtained similar in visual appearance to the bulky products of the previous examples. This yarn has a tenacity of 0.9 gram per denier at zero twist, a denier of 80 and about 15 detectable crunodal loops per inch.

Example VII

A 70/30 mixture of polyacrylonitrile (having an inherent viscosity of 1.4 in N,N-dimethylformamide) and tetramethylene sulfone is prepared by spraying the tetramethylene sulfone into a mechanically stirred polyacrylonitrile powder. This mixture is milled (rubber mill) at 200° C. with both rolls operating at a linear speed of 27 feet per minute, and with the plasticized polymer confined by dams set 2 inches apart. A film 3½ inches wide and 0.2 mil thick is obtained after one pass through the mill. Plasticizer is extracted from the resulting film with hot water. A ¼ inch strip of the resulting fibrillatable film is converted into a strong bulky yarn by passing through a jet device in accordance with the procedure of Example VI. The yarn is similar in visual appearance to those produced by the previous examples and is characterized by a denier of 1600, about 60 free ends and about 20 loops per inch.

Example VIII

A solution containing 17% by weight of polyacrylonitrile (having an inherent viscosity of 1.4 in N,N-dimethylformamide) in N,N-dimethylformamide is cast into a film at 110° C. using a 20 mil doctor knife. After removing the solvent from the film which is about 1.5 inches wide and 0.002 inch thick, the film is drawn 8× in the presence of steam at atmospheric pressure. The film is passed through an air jet device similar to that of Example I but having a slightly larger bore to accommodate the larger size film strip. Air pressure of 60 lbs./sq. in. is used. The product is a bulky yarn similar in physical appearance to those produced by the above procedures but having a tenacity of 0.8 at zero twist, a denier of 2000, and about 80 crunodal loops per inch.

Example IX

The oriented film strip of Example VI is given a twist of 6 turns per inch on a conventional textile down twister.

This film is fibrillated by passing the twisted film strip at a speed of 50 y.p.m. through the jet shown in FIGURE 1, using air at a pressure of 40 p.s.i. After passing through the jet, the product is relaxed by passing over a hot plate at 180° C. The 80 denier bulky product obtained has a tenacity of 3.2 grams per denier and an elongation of 17%.

This product is woven into a broadcloth fabric which shows covering power and uniformity superior to that obtained from spun yarns of the same polymer. In addition, these fabrics possess soft, dry, silk-like tactile properties which are highly desirable in fabrics for uses such as shirting and slips. The outstanding covering power obtained by using these bulky products is demonstrated in knitted tricot fabrics, which show light reflectance 77% vs. 50% for conventional nylon tricot of the same weight (3 oz./yd.²) and light transmittance of only 4.5% vs. 15% for the same nylon tricot.

Example X

The drawn film strip of Example VIII is given a twist of 3 turns per inch and fibrillated by the process of Example VIII. A bulky yarn is obtained with a denier of 1900. A three-ply yarn of 5700 denier was made from this sample. The yarn was tufted into a woven jute backing to form a cut pile carpet of the following specifications:

Pile height: ¾-7/16"

Gauge: 5/32"

Stitches/in.: 6-6.5

"Take up:" 28.5 ob. of pile yarn/sq. yd.

Backing: Jute, 12 oz./sq. yd.

Latex: GRS, room temperature curing type

The carpet showed very desirable fullness of hand, good "bounce" (resilience), good covering power, and good "tuft definition" (resistance to intermingling of tufts). In these properties the sample is superior to good quality wool or nylon filament carpets.

Example XI

Polyethylene terephthalate polymer with a relative viscosity of 35 was extruded at about 285° C. through a circular die with a diameter of 0.300 inch and slot widths of 0.010 inch at a rate of 3 grams per minute. To prevent collapse of the extruded tubing, nitrogen was supplied through the center of the die at a pressure of approximately 0.1 millimeter of mercury. Immediately below the die the extruded tubing was quenched by air flowing through a porous, sintered metal sleeve 19 millimeters in diameter and 65 millimeters in length. After leaving the quench sleeve the tubing was collapsed and drawn away by a set of pinch rolls 2¼ inches in diameter driven at a linear speed of 145 y.p.m. It was next passed to a conventional yarn windup bobbin also operating at 145 y.p.m. By suitably adjusting the nitrogen pressure within the tubing and the rate of flow of the quench air, a uniform, flattened tube was produced at any desired width up to about 5 millimeters and a corresponding double-wall thickness of about 5 microns or more.

The flattened tube was drawn 3.6× over a hot pin at 75° C. and then redrawn to a total of 4.5× over a plate at 145° C. It was next twisted to 10 turns per inch on a conventional textile downtwister, and passed through the air jet FIGURE 1 using a pressure of 17 p.s.i. to produce a bulky multifibrous yarn. The input speed of the flattened tube was 50 y.p.m., and the removal speed of the fibrillated product was 3% slower. A satisfactorily fibrillated yarn was also prepared from the drawn, untwisted ribbon. The bulky yarn was relaxed 6% by passing it over an 80° C. hot plate.

The final yarn thus prepared has a soft, pleasing hand with bulk and covering power equivalent or superior to that of spun yarn of the same polymer at the same denier. The yarn has a denier of 60, tenacity of 2.5 grams per denier, elongation 16%, and modulus of 60

grams per denier. Cross sections of the yarn show that there are about 50 individual ribbon-like fibrils in the yarn bundle ranging in width (or long dimension) from about 10 to 100 microns and about 5 microns in thickness. The yarn has improved affinity for disperse dyes at room temperature in comparison with conventional multifilament yarns of the same polymer and having roughly the same filament dimensions.

The novel process of this invention thus affords an economical route to the production of valuable textile yarns. Although it has been previously known that multifibrous strands could be produced from films, there has never been demonstrated a commercially feasible method for the production of strong, uniform, bulky strands of satisfactory covering power and tactile properties which can be directly employed in the manufacture of high-quality textile fabrics. Air jet devices have been in commercial use for texturing or increasing the bulk of conventional yarns, but have never been employed on film strips to produce the multifibrous yarns of this invention.

This application is a continuation-in-part of application Serial No. 665,078, filed June 11, 1957, now abandoned, and Serial No. 858,667, filed December 10, 1959, and now abandoned.

I claim:

1. A bulky yarn of high covering power and good tactile

properties comprising an integral network of interconnected random-length fibrils of a crystalline synthetic organic high polymer, said fibrils being substantially interlaced within said yarn and having an essentially trapezoidal cross section wherein the thin dimension is between 1 and 15 microns and the average long dimension is between 4 and 100 microns, said yarn having more than 10 free fibril ends per inch and a zero twist tenacity greater than .5 gram per denier.

2. The product of claim 1 having a cotton count higher than 30.

3. The product of claim 1 having a substantial number of crunodal loops.

4. The product of claim 1 wherein the average long dimension is between 4 and 50 microns, and the free fibril ends number more than 20 per inch of yarn.

References Cited by the Examiner

UNITED STATES PATENTS

2,853,741	9/1958	Costa et al.	161—168 XR
2,869,967	1/1959	Breen	57—140
2,920,349	1/1960	White	264—140
2,954,587	10/1960	Rasmussen	264—140 XR

ALEXANDER WYMAN, *Primary Examiner*.

JOSEPH REBOLD, *Examiner*.