Oct. 7, 1969 C. W. KIM 3,470,594

METHOD OF MAKING SYNTHETIC TEXTILE YARN

Filed March 30, 1967

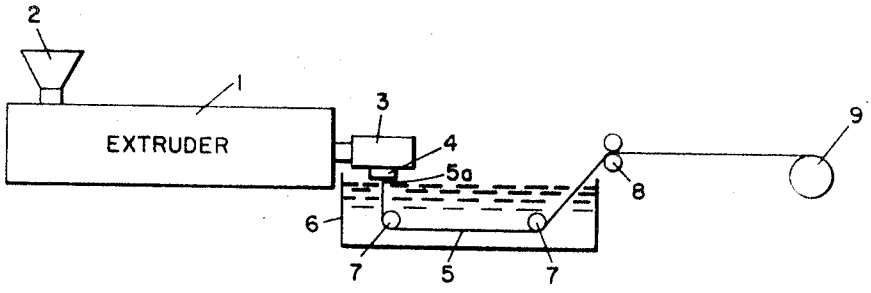


FIG. 1

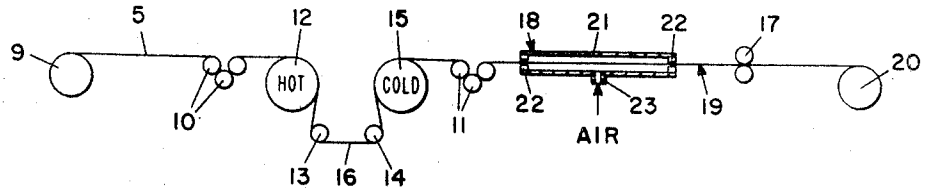


FIG. 2

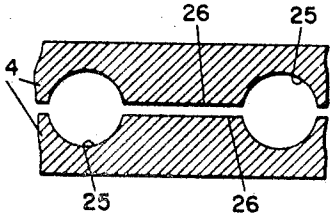


FIG. 3

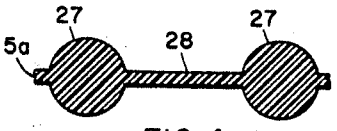


FIG. 4

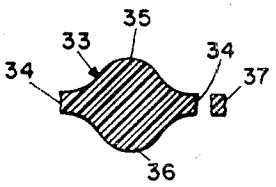


FIG. 10

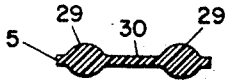


FIG. 5

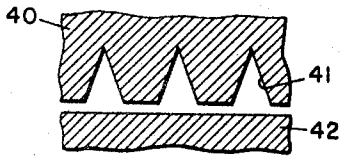


FIG. 11

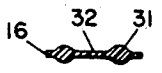


FIG. 6

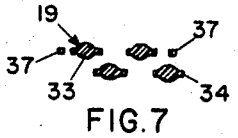


FIG. 7

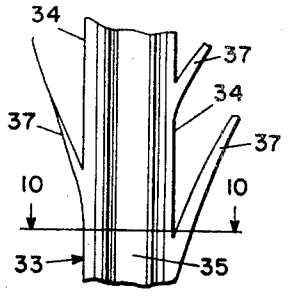


FIG. 9

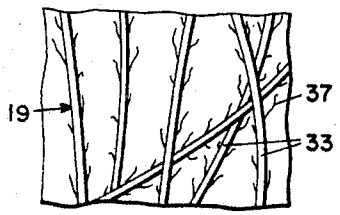


FIG. 8

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METHOD OF MAKING SYNTHETIC TEXTILE YARN

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U.S. Cl. 28—72 2 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to a method of making a bulky synthetic yarn having a spun-like appearance and comprised of filaments having a cross-sectional depth that is at a maximum at the transverse midpoint and decreases in both directions laterally to the minimum depth at the opposite edges thereof and a plurality of fine denier fibrils protruding from the side edges, said method being characterized by air-jet fibrillation of a linearly oriented striated film.

The present invention relates to a method of making a yarn of synthetic polymers and particularly to yarn formed from a relatively narrow strip or ribbon of film, which yarn, while it consists of continuous filaments, has a so-called spun look, that is, a bulky appearance characterized by a plurality of fiber ends extending laterally from the yarn in the manner of the fiber ends in a yarn spun from short length fibers or staple.

In the most commonly used methods employed in the production of synthetic yarn, the yarn is formed from a plurality of continuous filaments that are simultaneously extruded in a molten condition and are melt drawn to a reduced diameter. The filaments are subsequently drawn at an orienting temperature, which drawing further reduces the diameter of the filaments and imparts strength thereto. The filaments are then twisted into yarn. The linearity and surface characteristics of the filaments so formed affect the yarn both in physical properties (e.g., strength, filament density, and frictional and thermal characteristics) and in appearance (e.g., bulk, softness or hand, and light reflectivity). To modify the appearance and physical properties of the yarn, the yarn is usually further processed through a bulking or crimping operation wherein a permanent crimp is imparted thereto.

Yarns have also been produced from synthetic fibers by cutting the continuous filaments, usually in the form of tow, into short lengths or staple and processing them, for example, in the same manner as cotton and wool fibers are normally processed. Yarns so produced have an apparent breaking strength that is reduced relative to continuous filament yarns of comparable denier and are more expensive to process, but they can be formed of different fibers blended to achieve various effects, and have improved appearance and hand relative to the continuous filament yarns.

Processes have also been developed heretofore for producing continuous filament synthetic yarns from uniaxially oriented plastic film in the form, for example, of narrow strips slit from a wide sheet of film. In such processes, the film is reduced to filaments to form a multifilament yarn by mechanical working such as by brushing, rolling or twisting, or by the action of an air jet. Because handling and working a film is generally easier than handling or working a plurality of individual filaments, it is usually less expensive to produce continuous filament yarn from film than from individually formed filaments. However, with filaments formed from film, there is no control of the width of the filaments other than the inherent weakness of the film in the direction transverse to the direction of orientation. Thus, there are appreciable variations in the width of the filaments along their lengths, with corresponding variations in the strength, hand and appearance of the yarn, and there are many broken or run-out filament ends.

In making continuous filament yarn from film, an advantage of using a jet of air to separate the film into individual filaments rather than mechanical working is that the jet not only splits the film but the turbulence thereof also acts to intermingle the filaments, which contributes to the cohesiveness of the yarn and reduces the twisting required to form the filaments into a yarn. There is also a certain number of filaments broken to produce ends that, in the yarn, project laterally in the manner of the fiber ends in a spun yarn so that the yarn formed from these filaments tends to simulate the appearance of a spun yarn. In such a yarn, however, since the ends are formed by broken filaments, the strength of the yarn is reduced relative to the strength of a corresponding yarn of continuous or unbroken filaments and the number of such filament ends that can be accommodated is therefore limited. At the same time, since the ends generally correspond in cross section to the cross section of the filaments, they tend to be relatively coarse and thus their effect upon the hand or softness of a fabric produced from such a yarn is limited. Examples of the use of an air jet for splitting an oriented film into filaments are found in Patents Nos. 3,214,899 and 3,242,035.

It has also heretofore been proposed to produce synthetic yarn from strips of striated film, that is, from film having a plurality of spaced parallel longitudinally extending filament-forming portions or striations that are generally circular in cross section and are connected together longitudinally by integral webs of reduced thickness. Such films may be used in ribbon form, as illlustrated in Patent No. 3,164,948, or in a random or partial split form as disclosed, for example, in Patent No. 3,273,-771 and in Japanese patent publication No. 16,450/65. Yarns formed in this manner have generally been formed for the purpose of obtaining more flexible yarns than were obtainable by conventional melt-spinning processes, that is, in comparing a striated ribbon with a monofilament of comparable denier, the individual striations of the ribbon are smaller as well as easier to form on a commercial basis and the yarn is also more flexible. Among the other advantages of striated film, the webs define lines of weakness whereby the film can be readily split along the webs as by tearing or brushing. A further advantage of striated film is that, with a limited amount of splitting at the web and the individual striations or filaments thus connected together by the unsplit portions of the web, a reduced amount of twisting is required to form the filaments into a yarn.

Notwithstanding the fact that the prior art includes various methods for splitting film into filaments, various attempts to produce a bulky appearance in a continuous filament yarn, and various examples of the use of striated film, for example in making cordage, there has not heretofore been produced a synthetic yarn having tensile strength substantially equal to a continuous filament yarn of comparable denier while having the appearance and hand of a spun yarn, and having improved bulk and the corresponding covering, thermal and frictional characteristics.

Accordingly, the objects of this invention are to provide a method for making a bulky synthetic yarn having the appearance and hand resembling that of a yarn spun from staple and having improved covering capacity, insulation and tensile strength.

A further and specific object of this invention is to provide a method for making a continuous filament syn-

thetic yarn having a plurality of laterally projecting side hairs or fibrils of reduced cross section and wherein the number and length of such side hairs or fibrils are relatively large.

A further object of this invention is to provide a method for producing a synthetic yarn in accordance with the above objects, which method is inexpensive to practice, which reliably produces a quality product, and wherein the length and number of the side hairs or fibrils on the filaments can be controlled to produce various effects.

In accordance with the method of this invention, the above objects have been achieved by providing a strip or ribbon of striated film that is highly oriented uniaxially in the longitudinal direction, which strip is split into a plurality of individual filaments by a jet of air or other fluid impinging upon the strip in a direction substantially normal to the ribbon. When a strip of film having a cross section in accordance with this invention is acted upon in this manner, the film splits lengthwise along each of the webs with surprising regularity and with no discernible migration of the splitting across any of the striations. Thus, there is produced a yarn in which the individual continuous filaments formed from the striations are very uniform in cross section lengthwise of the filaments. At the same time, there is formed from the webs a plurality of fibrils or side hairs on each of the filaments, which fibrils have a reduced cross section relative to the cross section of the filaments. The number of fibrils and the length of them as well as the efficiency in the separation of the striations are primarily a function of the dimensions of the striated film and its cross sectional profile, the degree of orientation, the characteristics of the jet, the characteristics of the polymer such as its molecular weight, and the process conditions such as the temperature of the film.

For a more complete understanding of this invention, a preferred embodiment thereof is hereinafter disclosed with reference to the accompanying drawings, in which:

FIG. 1 is a schematic illustration of equipment employed in making a striated film in accordance with this invention.

FIG. 2 is a schematic illustration of equipment employed in orienting and fibrillating striated film.

FIG. 3 is a fragmentary detail sectional view of the die lips of the extruder illustrated in FIG. 1.

FIG. 4 is a fragmentary detail cross sectional view of a striated film approximately as it may appear immediately upon extrusion from the die lips of FIG. 3.

FIG. 5 is a view similar to FIG. 4 of the striated film after it has been melt drawn.

FIG. 6 is a view similar to FIG. 5 of the striated film after it has been oriented.

FIG. 7 is a view of the striated film of FIG. 6 after fibrillation.

FIG. 8 is a fragmentary plan view of the yarn of FIG. 7.

FIG. 9 is a fragmentary view on an enlarged scale of one of the filaments of the yarn of FIG. 7.

FIG. 10 is a cross sectional view taken substantially on the line 10—10 of FIG. 9.

FIG. 11 is a view similar to FIG. 3 but illustrating the die lips for making a single striated film strip.

In the drawings, there is illustrated schematically a conventional extruder 1 having a hopper 2 at the input thereof. At the discharge end of the extruder 1 there is a metering device 3 having a discharge die 4 from which issues the as-extruded film strip 5*a* illustrated generally in FIG. 4. Immediately upon issuing from the die 4, the film strip 5*a* is melt drawn, the melt-drawn film strip being designated at 5. The melt-drawn film strip 5 is quenched, for example, in a quench tank 6 that is filled with a liquid, which may be water at tap temperature. The melt drawn of the film strip may be in the range of 3:1 to 10:1 or higher.

Located within the quench tank 6 are idler rolls or bars 7 for directing the film strip 5 to a pair of feed rollers 8 that effect the melt draw of the film strip. The rollers 8 operate at a peripheral speed sufficiently high relative to the speed at which film strip 5*a* is extruded to produce the desired melt draw of the strip 5. As illustrated, from the feed rollers 8, the film strip 5 is wound to form a film roll 9, although the film strip 5 could of course be led directly to a subsequent operation in a continuous process without intermediate winding and unwinding.

As illustrated in FIG. 2, the melt-drawn film strip 5 is pulled from the film roll 9 by a set of low-speed feed rollers 10. Between the low-speed feed rollers 10 and a comparable set of high-speed draw rollers 11, the film strip 5 is directed over a heated drum 12, a pair of idler rollers 13 and 14 and a cold drum 15. The heated drum is maintained at a temperature sufficient for heating the film strip to the optimum orienting temperature for the particular material and which, for example, may be about 130° C. for a film strip of polypropylene. The cold drum 15 is maintained at ambient temperature. The high-speed draw rollers 11 are operated at a peripheral speed relative to the low-speed feed rollers 10 to provide the desired draw ratio, which for example may be up to about 15:1, and with a melt draw ratio of about 4:1, is preferably about 6:1 or 8:1. Drawing the film strip occurs between the hot drum 12 and the first idler roll 13. The oriented film strip is designated 16. After drawing, the strip 16 is cooled by the cold drum 15.

The oriented film strip 16 is pulled from the delivery end of the draw rollers 11 by a pair of feed rollers 17. Between the rollers 11 and 17, there is a fibrillation device 18 that separates the film strip 16 into a yarn 19 that consists of a bundle of individual continuous filaments. From the rollers 17, the yarn 19 is taken up into a yarn package 20.

The fibrillation device 18 comprises a cylinder 21 having guides 22 in the opposite ends thereof and an air tube 23 in the side wall thereof. The guides 22, as illustrated, are in the form of plugs inserted into the ends of the cylinder and having central bores that serve as the guides for the incoming film strip 16 and the outgoing yarn 19. The air tube 23 comprises a tube arranged substantially radially of the cylinder 21 and located near the longitudinal center of the cylinder, the tube being connected at one end to a source of air under pressure (not shown) and at the other end to the interior of the cylinder 21 through an aperture in the side wall thereof.

In FIG. 3 there is illustrated in cross-section a portion of one set of die lips 24 for the die 4 for producing the film strip 5*a*. As shown, the die lips 24 have a matched series of opposed die grooves 25 equally spaced along the length thereof and separated by intermediate die faces 26. In their operative relation in the die 4, the die lips 24 are positioned with the opposed die faces 26 slightly spaced. Thus, as illustrated in FIG. 4, the film strip 5*a* comprises a plurality of substantially rounded filament-forming strips 27, which are herein referred to as the striations and which are arranged in spaced parellel relation and are interconnected by integral webs 28. In FIG. 5, the melt-drawn film strip 5 is illustrated in cross-section and as shown comprises a series of striations 29 and webs 30 corresponding respectively to the striations 27 and webs 28 of the film strip 5*a*. The relative dimensions of the film strips 5*a* and 5, as shown in FIGS. 4 and 5, roughly represent a melt-draw ratio of about 4:1. The oriented film strip 16 is illustrated in cross section in FIG. 6 and comprises a series of striations 31 and webs 32 corresponding respectively to the striations 27 and webs 28 of the as-extruded film strip 5*a*. The relative dimensions of the film strips 5 and 16 represent a draw ratio of about 6:1. In FIG. 7, there is illustrated in cross section a portion of the yarn 19.

As shown in FIG. 7, the film strip 16 has been split longitudinally of the webs 32 into a plurality of filaments

33. In FIGS. 9 and 10, there is illustrated somewhat schematically and on an enlarged scale a typical filament **33** of the yarn **19**. This filament comprises an individual striation **31** together with a portion of the web **32** on each side thereof, which web portions terminate in side edges **34** and which constitute the edges along which the webs **32** have been slit to separate the respective filament **33** from its adjacent filaments on the film.

The filament **33** has a shape that is generally round or, more particularly, has a maximum thickness substantially at its transverse center between an upper edge **35** and a lower edge **36**. Outwardly in both directions from the edges **35** and **36**, the thickness of the filament decreases to the minimum thickness at the side edges **34** equal to the thickness of the web **32** in the oriented film strip **16**. The configuration of the side walls of the filament **33** intermediate the edges **34**, **35** and **36** is a function of the draw ratios in the melt-draw and in the orientation and, with the film **5***a* as illustrated in FIG. 4, may be substantially circular as shown in FIG. 10. Lengthwise of the filament **33**, the thickness between the edges **35** and **36** and the width between the opposite side edges **34** are substantially uniform.

In addition to the fact that the film strip **16** has split into a plurality of individual continuous filaments **33** substantially corresponding in number to the number of striations **31**, the webs **32** have formed a plurality of fibrils or side hairs **37**, FIG. 9, at the opposed side edges **34**. Under the action of the air jet, the fibrils **37** are torn loose or run-out at one end from one of the two filaments between which it is formed and so define side hairs of varying lengths. Each of the side hairs **37** has a cross section that, except where broken, decreases from the base to a point at the free end. This apparently results from the lateral wandering or migration of the molecular orientation in the film between two adjacent filaments that is present even in highly oriented film. Since each fibril **37** has a thickness comparable to the original thickness of the web **32** from which it was formed and a width that at the base may be roughly equal to its thickness, the fibril **37** is substantially finer than a filament **33**.

In the yarn **19**, the number of filaments **33** corresponds to the number of striations **31** in the film strip **16** and this in turn is determined by the number of die grooves **25** in the die lips **24**. Inasmuch as the filaments **33** are all continuous and are not broken, the tensile strength of the yarn is determined by the polymer characteristics and is not dependent upon the degree of twist in the yarn as are yarns of staple or of broken filaments. Accordingly, twisting of the yarn is not necessary for purposes of strength so the amount of twist imposed upon the yarn need be no more than that required to establish coherence of the yarn, which requires a low level of twist, and can otherwise be selected for other desired effects. From this standpoint, since a high twist is not required, the yarn can be made quite loose and bulky with the resulting advantages of improved covering capacity and increased insulation for a given weight of yarn.

The fibrils or side hairs **37** of the filaments **33** contribute to the above advantages. Inasmuch as the fibrils **37** extend laterally relative to the filaments **33**, they tend to support the filaments in spaced relation to increase the bulk of the yarn relative to a comparable yarn of equal twist but without the fibrils. At the same time, the fibrils increase the covering capacity of the yarn and the insulation.

The free ends of the fibrils **37** extending from a fabric formed from the yarns **19** adds a softness to the surface of the fabric as well as creates the appearance of a fabric formed from spun yarn. The fineness of the fibrils **37** increases the softness of the fabric. With fiber ends formed by the fibrils or side hairs **37**, the breaking strength of the yarn is greater than it would be if they were formed by broken filaments.

A more complete understanding of the present invention will be had from the following specific example of one yarn-forming process. A polypropylene film was extruded through a die having die lips as shown in FIG. 3, the die lips having semicircular die grooves **25** with a radius of 6 mils and 30 mils from a point on one groove to the corresponding point on the adjacent groove. The die faces **26** were 18 mils wide and were spaced a distance of 2 mils from the corresponding die face **26** of the opposite die lip **24**. The total width of the die lips **24** was 2 inches and there were 67 of the die grooves **25**.

The as-extruded film strip **5***a* was melt drawn at a ratio of 4:1 to provide a melt-drawn film strip **5** having a total width of about 1.5 inches and striations **29** having a total thickness of about 5 mils. The strip **5** was oriented at a draw ratio of about 6:1 to provide the oriented film strip **16** having an overall width of about 0.7 inch, having striations **31** with an average total thickness of about 1.5 to 2.5 mils and a gauge or a distance from a point on one striation to the corresponding point on the adjacent striation of 10 mils, and having webs **32** with an average thickness of 0.5 to 1.0 mil.

The film strip **16** was fed through a fibrillation device **18** comprising a cylinder **21** that was 6 inches long and had an internal diameter of 0.75 inch, and had an aperture at the center thereof that was connected to an air tube **23** arranged radially of the cylinder **21** and having an internal diameter of 0.125 inch. Air at 40 p.s.i.g. was supplied to the tube **23**. There was a slight over-feed, for example, five percent, of the draw rollers **11** relative to the feed rollers **17**, so that there was limited play of the film strip **16** in the cylinder **21**. The film strip **16** was substantially completely reduced to individual filaments corresponding to the striations **31** of the film strip and there was no discernible migration of the splitting across any of the filaments so that all of the filaments were in fact continuous. On each filment, there was an average of about 6 fibrils 37 per inch, equally divided between the opposite sides thereof, which fibrils had an average cross section of about 0.5 mil compared to a filament diameter of about 3 mils, and varied in length from about $\frac{1}{32}$ inch to about $\frac{1}{4}$ inch, with an average length of about $\frac{1}{8}$ inch.

The yarn **19** can be formed of any polymer that can be extruded and drawn into an oriented striated film, for example, polyethylene, polypropylene, and copolymers of ethylene and propylene.

The yarns in accordance with the method described above are substantially linear, but, for the usual reasons, for example, resilience and covering capacity, may be bulked in any conventional bulking process such as stuffing box or knife edge crimping.

The number as well as the width and length of the fibrils **37** can be controlled by control of the width of the web **28** in the film **5***a*, the degree of orientation, the tension on the yarn at fibrillation, the direction and velocity of the jet, the polymer characteristics and the operating or process characteristics. Generally, a wider web in the film and more linear orientation lengthwise of the web will provide a greater number of and longer fibrils. As the tension on the yarn during fibrillation is increased, the number of hairs and lengths of them are reduced because the film is afforded less opportunity to wave or vibrate relative to the air jet and thus to be worked repeatedly by the jet. When the jet is directed lengthwise of the film rather than transverse to it, the degree of fibrillation or separation is reduced.

While the film strip is herein disclosed as extruded as a strip, it will be obvious that it could be formed either as a flat sheet or tube and subsequently slit into strips of the desired width.

While air is preferably used for the jet for the fibrillation of the film, it will be obvious that the jet may be provided by a gas or fluid other than air.

The degree of fibrillation or separation of the film into filaments under given circumstances can be increased if necessary by providing a second fibrillation device **18** arranged in tanden relative to the first device.

It will of course be apparent that the specific configuration of the striations **27** is not critical. Rather than circular as herein disclosed, they could for example be substantially diamond-shaped or square. At the same time, the striations could be single rather than double, that is, they could extend in one direction only from the web rather than in both directions from the web **28** as illustrated in FIG. 4. In FIG. 11, there is illustrated a die lip **40** for making a single striated film, which die lip comprises a plurality of die grooves **41** adapted to cooperate with a flat or straight die lip **42**. The single striated film has the advantage that it can be cooled by running it over a chilled roll and can otherwise be handled by engaging the flat face thereof without crushing or otherwise damaging the striations. Since the die grooves **41** are formed in only one of the die lips, the die lips are less expensive and the alignment of the die grooves **25** that is necessary in the opposed die lips **24** for making double striated film has been eliminated.

What I claim and desire to protect by Letters Patent is:

1. A method for making a bulky synthetic yarn having a spun-like appearance, said method comprising the steps of providing a film strip that is highly oriented uniaxially and has a plurality of spaced parallel striations longitudinally aligned with the axis of orientation and webs integral with and extending between said striations, passing said film strip through a pair of spaced film guides, and separating said film strip at a point intermediate said guides along said webs with the formation of fibrils from said webs by directing a fluid jet onto said film strip in a direction substantially normal to said strip of film thereby reducing said strip of film to a plurality of individual filaments consisting of individual striations together with a portion of the web at each side edge thereof and fibrils integral with said filaments at said side edges and extending laterally therefrom.

2. A method of making a bulky synthetic yarn having a spun-like appearance, said method comprising the steps of providing a film having a plurality of spaced parallel striations and webs integral with and extending between said striations, imparting to said film linear orientation with the axs of orientation aligned longitudinally of said striations, passing a strip of said film through a pair of spaced film guides, and separating said film strip at a point intermediate said guides along said webs with the formation of fibrils from said webs by directing a fluid jet onto said film strip in a direction substantially normal to said strip of film thereby reducing said strip of film to a plurality of individual filaments consisting of individual striations together with a portion of the web at each side edge thereof and fibrils integral with said filaments at said side edges and extending laterally therefrom.

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JOHN PETRAKES, Primary Examiner

U.S. Cl. X.R.

28—1; 57—157