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MacFarlane

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[54] YARN PROCESS

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[73] Assignee: **Fiber Industries, Inc.**

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[57] ABSTRACT

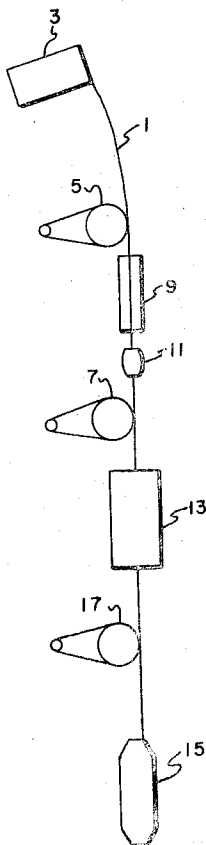
Textile denier, multifilament, false twist crimped, heat set stabilized polyester yarn characterized by liveliness and filamentation values and a simultaneous draw-texturing process for the production thereof.

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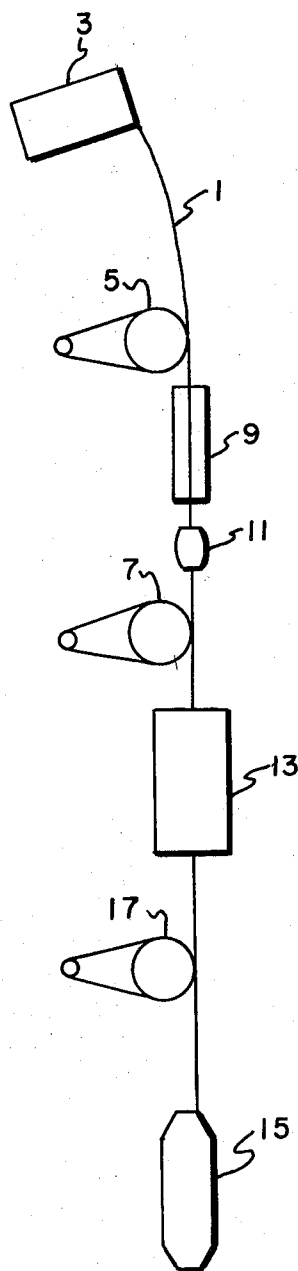
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15 Claims, 1 Drawing Figure



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YARN PROCESS

The present invention relates to a novel, draw-textured, stabilized polyester multifilament, textile denier, yarn suitable for fabric constructions, particularly knit and woven goods, requiring superior dimensional stability coupled with excellent yarn processability.

More particularly, the present invention relates to such a yarn of the false twist crimped type having a total denier of at least 30; a tenacity of about 3.0 to 4.0 grams per denier; an elongation of about 20 to 35 percent; about 30 to 85 crimps per extended inch of filament, a linear shrinkage under hot, wet conditions below about 15 percent, a liveliness factor of about 20 to 60 and a filamentation value of about below 0.4.

It has been recently suggested that the separate process stages involved in the production of false twist textured yarn can be combined into a simultaneous, sequential operation. Conventionally, a fiber producer spins a continuous filament yarn and then in a continuous or lagged operation therewith draws the yarn to a denier and tensile strength suitable for fabric construction. In a separate and distinct operation, the yarn is false twist crimped and then stabilized in continuous fashion by being overfed while subjected to heat or in a separate operation by being wound loosely onto a package which is then steam autoclaved. (See British Patent No. 787,619 and U.S. Pat No. 3,316,705). In any event, stabilization is achieved by hot shrinkage of the yarn. These conventional texturing operations on draw yarn are hereinafter referred to as "lagged operations" and the yarn thereby produced as "lagged operation yarn".

In order to improve the overall process efficiency as well as to make a better product, a process was conceived wherein undrawn yarn of textile denier would be fed into a false twist zone consisting sequentially of a heater, a false twister and a draw roll, the latter operating at a speed sufficient to draw the yarn at the desired draw ratio. The false twist backs up into the heated zone to a draw neck point located therein, wherein the twist is set into the yarn. The yarn is then sequentially, and in a continuous manner, overfed through a heater zone and packaged.

Although sound in principle, it was quickly found that the product of the improved process was different in certain respects as compared with yarn made by the lagged draw texture procedure, even though processing conditions were as closely tuned to the lagged process conditions as reasonably feasible. Most notably, the new yarn performed poorly during fabric construction.

It has now been discovered that a polyester multifilament yarn of a total denier of at least about 30, but generally below 200, and preferably 40 to 175, and a denier per filament of about 0.5 to 10 preferably 3 to 5.5, can be produced of somewhat lower tenacity where desired than lagged operation yarn but being characterized by superior fabric construction processability coupled with excellent dimensional stability in converted form. This invention relates to this novel product and a process by which it can be produced.

As compared with lagged operation yarn continuously stabilized which has a tenacity of about 4.0 grams per denier (gpd) and above, the yarn of this invention has a tenacity of about 3.0 to 4.0 gpd, usually about 3.2 to 3.8 gpd. Elongation of both yarns is about 20 to 35

percent. Although the feed yarn can be conventionally drawn to tenacities above about 4.0 gpd, such tenacities do not appear to be obtainable without the consideration of feed stock modification, detailed process optimization and the like, in the simultaneous draw texturing process. However, quite surprisingly yarn is produceable having a tenacity up to about 4.0 gpd which is superior to lagged operation yarn in knitting and weaving operations, and in final fabric stability—two areas where one could normally expect decreased tensile properties to be a hindrance.

Processability of a false twist textured, stabilized yarn is conveniently gauged by its liveliness factor and filamentation value. If the yarn is too lively it curls and kinks upon itself as it is withdrawn from the package and fed into the fabric construction machinery, resulting in tension fluctuation and ultimately machine stoppage. Likewise, yarn of high filamentation value indicates the presence of ruptured filaments and fluttering filaments which snag, catch and otherwise cause machine stoppage.

The yarn of the invention has a liveliness factor of about 20 to 60 while lagged operation yarn has a liveliness factor of above about 60.

Liveliness factor (Q) is calculated by experimentally determining in a numerical fashion (1) the tendency of the yarn to twist upon itself when in a relaxed state (designated A) and (2) the torque wrap number of the yarn when under a low tension such as applied during knitting and weaving operations (designated B). Liveliness factor is the product of torque wrap number and self-twisting tendency ($Q = AB$).

To determine A , a 10 inch sample of yarn is attached between two clamps along a scale ruled to hundredths of an inch in a manner so that the yarn does not become free to untwist while being so placed and is under no tension. Then a tension hook applying 6.5×10^{-4} grams per denier (based on the denier of the yarn) stress is placed at a point midway between the two clamps. By releasing one clamp, slack is pulled from the yarn until it is parallel with the ruled edge. The tension hook is adjusted to the midpoint of the yarn's length, if necessary. One clamp is then unlocked and slowly moved toward the stationary clamp until the yarn twists or kinks upon itself. The distance remaining between the clamps is recorded. A or self-twisting tendency is equal to the average value over ten observations. For the yarn of the invention A is below 2.0, preferably below 1.7, i.e., 1.3 to 1.6. Lagged operation yarn has a value of over 2.0 and generally 2.2 to 2.5. Testing is conducted after moisture equilibrium is reached at 65 percent relative humidity at 70°F. in a draft-free enclosure.

To determine B , or the torque wrap number, a 40 inch yarn is doubled and, the 20 inch length of yarn is held vertically, secured at both ends, at 35 percent relative humidity at 70°F., but under not tension. A tension weight to apply 0.02 grams per denier to the yarn is then attached to the lower end of the yarn and that end is released. After the yarn reached equilibrium, the number of twists in the 20 inch sample is counted and the torque wrap number is the number of twists minus any producer twist present. Again, an average of ten samples is used in the Liveliness Factor equation. For the yarn of the invention B is about 15 to

30 while lagged operation yarn has a value of over 30 and usually about 40.

Thus, the Liveliness Factor, which takes into account what are believed to be two of the prime yarn characteristics involved in poor knitting processability due to yarn liveliness, of the yarn of the invention is about 20 to 60, preferably about 30 to 45, most preferably about 35 to 40.

Filamentation during the draw-texturing process is most prone to occur between the spindle and the draw roll. This is because the highest tensions to which the yarn is subjected during draw texturing occur in that region of the operation wherein drawing tension is compounded by tension imposed by the spindle. In the usual lagged operation sequence, wherein the yarn is not being simultaneously drawn and false twist textured, the yarn is not under drawing tension and 50 to 60 turns per inch of false twist are inserted into the yarn. Thus, the yarn has been drawn at its optimized draw ratio, say about 3.65 for polyethylene terephthalate yarn, of spun birefringence about $5.8 \cdot 10^{-3}$ and spun I.V. about 0.63 and then separately false twist textured. However, when these conditions are combined in simultaneous draw texturing, tenacity drops slightly but filamentation of the yarn significantly increases at the conventional lagged operation twist insertion level of about 55 turns per inch. Filamentation can be eliminated by significant draw ratio reduction i.e. 3.2 but with corresponding deterioration in tenacity i.e. 2.5 grams per denier. However, it has been quite unexpectedly found that in the simultaneous draw texturing operation, actual tension as measured along the yarn longitudinally decreases with increase in twist level which results in improved tensile properties, particularly tenacity, by enabling the use of a higher draw ratio and reduced filamentation. In fact, filamentation value without deleteriously influencing tenacity and elongation, can be decreased from about 10 to 30 at about 55 tpi; to about 0 to 0.4 at the higher twist frequency levels based on 150 to 170 denier yarn.

In fact, yarn filamentation decreases to where it is below that of the lagged operation yarn as determined by filamentation value, disclosed more fully hereinafter. Although not entirely understood, it is believed that higher twist translates a greater proportion of the total drawing and spindle induced tension into a force vector perpendicular or tangential to the longitudinal axis of the yarn, thereby reducing the tension component which the yarn must bear in the lengthwise direction. Thus, higher draw ratios corresponding to higher filament tensions can be employed, i.e., draw ratios approaching the optimized draw ratio of about 3.60 to 3.70 can be employed, i.e., 3.40 to 3.55. Heretofore, to avoid excessive filamentation, draw ratios in the simultaneous draw texturing process of the order of about 3.2 were believed to be about the highest useable in practice.

Filamentation value characterizes the yarn not only in a physical sense but is indicative of its improved performance properties, as will be apparent. This is because the characteristic relates directly to the number of times a fabric construction machine, in this case a knitting machine, will be stopped per unit length of fabric due to yarn filamentation. In other words, the theoretical and visual improvement by selection of yarn

processing conditions translates into improved fabric construction efficiency.

Filamentation Value is based on knot free yarn and is the actual number of machine stops due to filamentation (most usually a loose filament caught underneath adjacent layers of yarn on the feed package) per 30 feeds (30 feed packages) per 10 fabric yards on a Fouquet Interlock Knitter. The knitting machine is set to 15 to 18 rotations per minute with the machine stop mechanism being set at medium sensitivity.

The yarn of the invention has a Filamentation Value below 0.4, usually about 0.1 to 0.3. Yarn produced by draw texturing at the low twist insertion levels but at draw ratios sufficient for a tenacity of at least about 3.0, has a Filamentation Value of about 10.0 to 30.0; lagged operation yarn has a Filamentation Value of about 0.4 to 1.0.

Although the yarn of the invention in certain instances is not as strong, as measured by tenacity, as lagged operation yarn, it performs in a superior fashion in final fabric form as regards maintenance of shape definition. This is believed to be characteristic of the yarn of the invention because of its method of manufacture which apparently imparts a high degree of resiliency or recovery to the yarn as can be measured by the "dynamic cycle stretch yarn" test.

The dynamic cycle stretch test measures the amount of work required to extend an end of relaxed yarn after it has been extended a given number of times at a defined load. A higher value correlates with enhanced fabric stability. The yarn of the invention has a dynamic cycle stretch test value of above about 1.8, preferably about 2.0, but generally below about 2.5. Lagged operation yarn has a value of about 1.0 to 1.6, which is significantly lower. The dynamic cycle stretch test value is determined as follows:

APPARATUS

A constant-rate-of-extension tester such as the Instron, which will draw a closed-loop extension-recovery curve is required. This should preferably be equipped with an integrator to measure the work of extension. The instrument is adjusted to draw a closed-loop extension-recovery curve. The following settings are used:

Full Scale Load	0.2 gm. per den.
Gauge Length	2.5 in. (63.5 mm)
Head Speed	2 in. per min.* (50.8 mm. per min.)
Chart Speed	5 in. per min. (127.0 mm. per min.)

* It may be desirable to vary the head speed depending on maximum yarn stretch.

PROCEDURE

1. Skein 5 yards (4.57 m) of yarn under low tension. Relax in water at 140° to 158°F. (60° to 70°C.) for 10 minutes and centrifuge. Dry in tensionless state, and condition for 1 hour in a standard atmosphere at 70°F. (21°C.) — 65 percent RH.
2. Cut four samples of yarn approximately 5 in. (127.0 mm.) long when in relaxed state.
3. Attach a weight of coiled copper wire to the end of each sample equivalent to 0.002 gm. per den. of original yarn. Attach the other end of each sample

to a rack or horizontal bar so that the yarns can hang freely.

4. Using a clamp weighted (equivalent to 0.1 gm. per den.), subject each yarn in turn to this tension, removing the clamp after one or two seconds so that the yarn is again hanging freely under 0.002 gm. per den. tension. The purpose of this step is to remove the tangled fibers which result from skeining, scouring, and drying, and which would otherwise interfere with the accuracy of the test.
5. After a minimum of 15 minutes, place sample in the tester so that the 2½ in. (63.5 mm.) gauge length is attained while the yarn is under a tension of 0.002 gm. per den.
6. Operate the tester so that the sample is cycled five times between original gauge length and that which creates a force of 0.1 gm. per den. (recorder pen half way across chart). Record integrator reading for each of the extension and recovery cycles. After the third or fourth cycle, the decrease in these readings should be less than five percent. For routine testing, only the reading of the fifth extension cycle is needed.

CALCULATIONS

Values of percent stretch and the work stretching of the fifth cycle are calculated from the Instron chart and the integrator reading.

The following Example illustrates the yarn of the invention and the production thereof.

EXAMPLE

An as spun 510/36 yarn of linear fiber-formable polyethylene terephthalate (having an intrinsic viscosity of about 0.63, a birefringence of about $\sim 5.7 \cdot 10^{-3}$ polymerized from polyester monomer produced by the direct esterification of terephthalic acid with ethylene glycol, such polymer having a free glycol content of less than about 2.25 mol percent) is draw textured in a continuous operation in accordance with the following process conditions and with reference to the Drawing.

The undrawn yarn having a producer twist of about 0 turns per inch, is supplied from supply package 3 to the draw texturing operation. The yarn is pulled off of the supply cheese by positively controlled feed roll 5. Draw roll 7 is operated at a peripheral speed so that the yarn is drawn 3.45 times, based on feed and draw roll surface linear speeds in the drawing zone between feed roll 5 and draw roll 7. Hot plate 9, heated by internal steam generating means and 3.25 feet long, is maintained at about 230°C. False twist spindle 11, being of the tube type having a centrally-located sapphire pin about which the yarn is wrapped once, is rotated by means not shown at about 370,000 rotations per minute. Yarn speed around the draw roll is about 440 feet per minute, so that about 70 tpi (turns per inch) of twist is put into the yarn upstream of spindle 11 while the same amount of twist is taken out of the yarn downstream of the spindle, in accordance with conventional false twisting principles. The 70 tpi runs back from the spindle, along the yarn as it passes across the heater to the draw point, which is located about 2.5 inches below the top of the heater plate 9, thus setting the yarn in the twisted configuration. The draw point is precisely located without the use of external means

such as a draw pin by the dynamic conditions of the draw texturing process. Because of the change in yarn denier at the draw point, tpi above the draw point is no more than about 15 to 20 and gradually dissipates as it runs back toward the feed roll 5. From the drawing texturing zone, the yarn, now about 150/36, passes immediately and sequentially into a 3 foot long hot air chamber 13 maintained at about 190°C. at a 16 percent overfeed as measured between draw roll 7 and relax roll 17. In the relaxation zone, the drawn, crimped, torque lively yarn is stabilized for subsequent use in knit and woven fabric constructions requiring dimensional stability, stitch definition and the like properties not obtainable with "stretch yarns" that have not been stabilized. The yarn is then fed to package 15 at about 7 percent underfeed to form a firm package construction suitable as a feed package for knitting and weaving processes. The yarn has the following characteristics:

Tenacity	3.2 gpd
Elongation	22%
Linear Shrinkage	5%
Liveliness Factor	32
Self-twisting Tendency	1.6
Torque Wrap Number	20
Filamentation Value	0.2
Dynamic Cycle Test	
Stretch Value	2.1
*Crimp Frequency	34 crimps per extended inch of filament

* Five individual filaments are removed from the yarn bundle at points spaced from the outside to the center thereof. Each filament is extended fully, but not stretched, and the number of crimps per extended inch counted. The average of the five values is the crimps per inch of the yarn based on extended filaments which is about 30 to 35 for the yarn of the invention. (30 to 45 for 145 denier and above and where desired 45 to 85 for the lower denier yarns.)

Linear shrinkage is measured after 30 minutes in boiling water as linear shrinkage per unit length under a tension of 0.045 grams per denier. Preferably, the yarn of the invention has a linear shrinkage below 10 percent, most preferably below about 5 percent.

With reference again to the drawing, the following is a more general disclosure of the process used to produce the improved yarn of the invention.

Heater 9 is maintained at a temperature of about 180°C. to 240°C. preferably 210°-240°C. for enhanced dye uniformity. When a heater having a gradual temperature profile along its length is used, the temperature stated is the maximum measurable temperature. The heater may be of any suitable shape and form, as the grooved plate type or of the hot air box convection type. The plate type is preferred because with polyethylene terephthalate yarn, or with many other synthetic polymer yarns, the yarn will melt if heated in undrawn state above the second order transition temperature of the polymer (90°C. - 100°C. with polyethylene terephthalate). Drawn yarn can be subjected to the higher temperatures employed in the simultaneous draw-texturing process, but drawing will not take place unless the yarn is heated above ambient conditions. Thus, the yarn is held off but near the heater plate until draw texturing is taking place and is then placed in direct contact with the heater. Conductive heaters may be heated electrically or by other means such as by steam or hot air flowing through a tube positioned beneath the surface of the heater. The heater will be about 2 to 6 feet long, usual about 3.3 feet long.

The twister will generally be of a conventional spindle type. Preferred for balance purposes is a tubular spindlet having a twist trap pin centrally located across its diameter about which the yarn is wrapped once. The spindle is driven by a motor at speeds of about 300,000 to 600,000 rpm, and above, i.e., 800,000 rpm. Various threadline stabilizers, such as tubes and guides, many of which are well known in the art, can be positioned above and below the twister. With lower denier yarns, approaching the 40 denier area, friction false twisters such as one or more revolving bushes, flanges and cups arranged for sequential and/or simultaneous yarn contact can be employed. Yarn speed is correlated with twister speed to insert the desired number of turns per inch into the yarn.

A spin finish of the type imparting good, that is low, fiber to twist trap pin friction characteristics to the yarn will be applied to the yarn prior to the draw texturing operation or therewith but prior to the first heater. This is done so that excessive tensions are not imposed on the yarn by the twister, which would contribute to filamentation. Finishes suitable for this purpose are those routinely employed in the art, for example those containing lubricants such as hexadecyl stearate, high viscosity mineral oil, polysilicones, and the like. The draw-texturing process should be operated so that the ratio of tension above the spindle to the tension below the spindle is about 1:1.5 to 1:2.5, preferably about 1:1.7 to 1:2.3. In preferred numerical values, the measureable tension along the strand path above the twister is about 0.118 to 0.180 rams per denier based on the drawn yarn denier and about 0.236 to 0.420 grams per denier below the twister, also based on drawn yarn denier.

The feed and draw roll means are of a non-slipping, positively controlled type, for example a draw roll and spaced-apart associated separation roll about which the yarn is wrapped a plurality of times, or of the endless belt "casablanca" type.

The second heater is conventionally of the enclosed convection type, although plate type heaters can be employed, and is maintained at about 150°C. - 240°C., preferably about 170°C. - 210°C. The second heater stabilizes the yarn and has a primary influence on the degree of bulk in the yarn on the package, which is relaxed about 10 to 30 percent, preferably about 12 to 20 percent as it passes through the second heater zone. Generally, the higher the first heater temperature and the lower the second heater temperature, the higher the bulk of the yarn on the take-up package. For practical purposes, degree of bulk on the package may be considered to be overfeed minus linear shrinkage, with greater linear shrinkage occurring at higher second heater temperatures. From the heat stabilization step, the yarn is underfed about 5 to 10 percent to the take-up package in order to form a package of sufficient hardness and stability suitable for use to feed yarn into knitting and weaving operation.

Various modifications of the invention will appear obvious to those skilled in the art. For example, although the invention has been exemplified with polyethylene terephthalate, fibers formed of other fiber-formable polyester, as well as fiber-forming polyamides and blends thereof are useable in conjunction with the present invention.

It will be further understood that, while the Example describes a unitary operation involving passage through a second heater, the advantageous properties of the yarn of this invention induced by high-twist level simultaneous drawing and texturing may be secured in a lagged operation involving a separate autoclave step, or second heater and autoclaving steps might be usefully combined. For 145 to 170 denier yarn, about 60 to 80, preferably 68 to 75 tpi is inserted into the yarn in accordance with the inventive process. With decreasing denier yarns, twist insertion level can be raised even higher if yarn speed is accordingly sacrificed.

What is claimed is:

1. A textile denier polyester multifilament, false twist crimped, stabilized yarn having a denier per filament of about 0.5 to 10, a tenacity of about 3.0 to 4.0 grams per denier, an elongation of about 20 to 35 percent, a linear shrinkage below 15 percent, a liveliness factor of about 20 to 60 and a filamentation value of about below 0.4.

2. The yarn of claim 1 wherein the polyester is polyethylene terephthalate and the yarn has a denier of about 145 to 175.

3. The yarn of claim 2 wherein the yarn tenacity is at least 3.2 grams per denier, linear shrinkage is below about 10 percent, the liveliness factor is 30 to 45 and the filamentation value is 0.1 to 0.3.

4. The yarn of claim 3 wherein linear shrinkage is below about 5 percent and the liveliness factor is about 30 to 35.

5. The yarn of claim 2 wherein the torque wrap number is 15 to 30 and the self-twisting tendency is below 1.7.

6. The yarn of claim 5 wherein the self twisting tendency is 1.3 to 1.6.

7. The yarn of claim 2 wherein the dynamic cycle stretch test value is above 1.8.

8. The yarn of claim 2 wherein the dynamic cycle stretch test value is 2.0 to 2.5.

9. In a process for producing a 145 to 170 denier false twist crimped polyester multifilament yarn, wherein an undrawn or partially undrawn polyester yarn is fed into a simultaneous drawing and false twist crimping zone consisting of a heater and false twister positioned between a feed means and draw means and wherein the false twist backs upstream into the heated zone wherein the false twist is set into the yarn and wherein the yarn necks at a draw point without the presence of snubbing means, the improvements which comprise inserting about 60 to 80 turns per inch of false twist into the yarn while drawing the yarn about 3.40 to 3.55 times to produce a yarn having a tenacity of at least 3.0 gpd and an elongation of at least 20 percent.

10. The process of claim 9, wherein the yarn tension on the yarn along the longitudinal axis thereof is about 0.118 to 0.180 grams per denier above the false twister and about 0.236 to 0.420 grams per denier below the false twister.

11. The process of claim 9 wherein 68 to 75 turns per inch of false twist is inserted into the yarn.

12. The yarn of claim 3 wherein the crimps per extended inch of filament is about 35 to 45.

13. A knit fabric comprising the yarn of claim 1.

14. A knit fabric comprising the yarn of claim 12.

15. The yarn of claim 2, made by being false twist crimped and drawn in a simultaneous false twist crimp-draw process step.

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