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(54) STAPLE YARN MANUFACTURING PROCESS

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(57) **ABSTRACT**

The present invention is a staple-fiber yarn, an apparatus for producing the yarn, and a process for stretch breaking filament yarns to produce the staple yarn. The process enables the production of a plurality of products of lot size smaller than a large denier tow product. The process includes a draw zone, a tension control zone, a stretch-break zone and a consolidation zone to form a yarn of staple fibers.

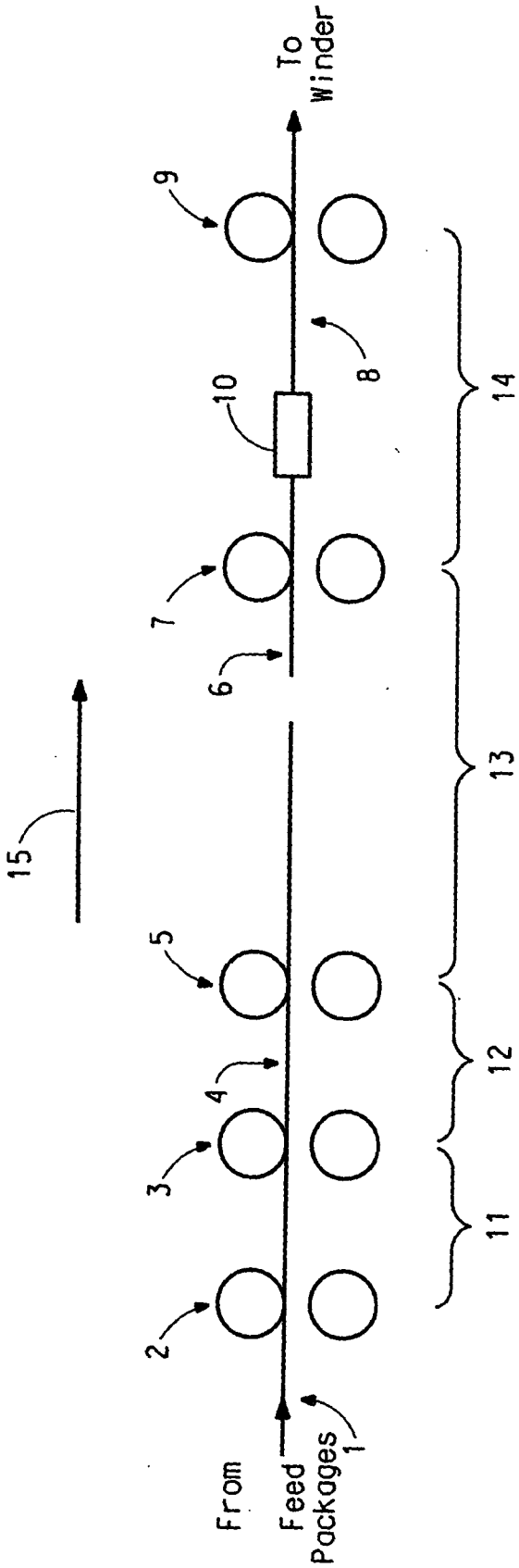
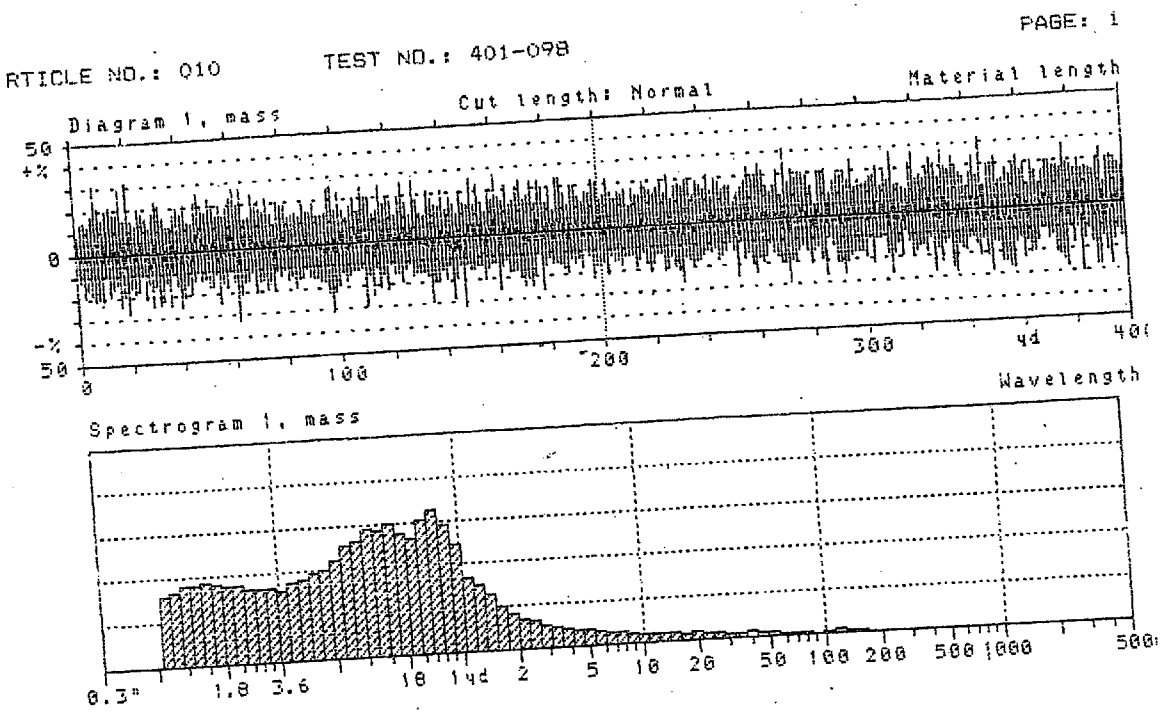


FIG. 1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50
+%
0
-%
50
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100
200
300
400
Wavelength
Spectrogram 1, mass
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3.6
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14d
2
5
10
20
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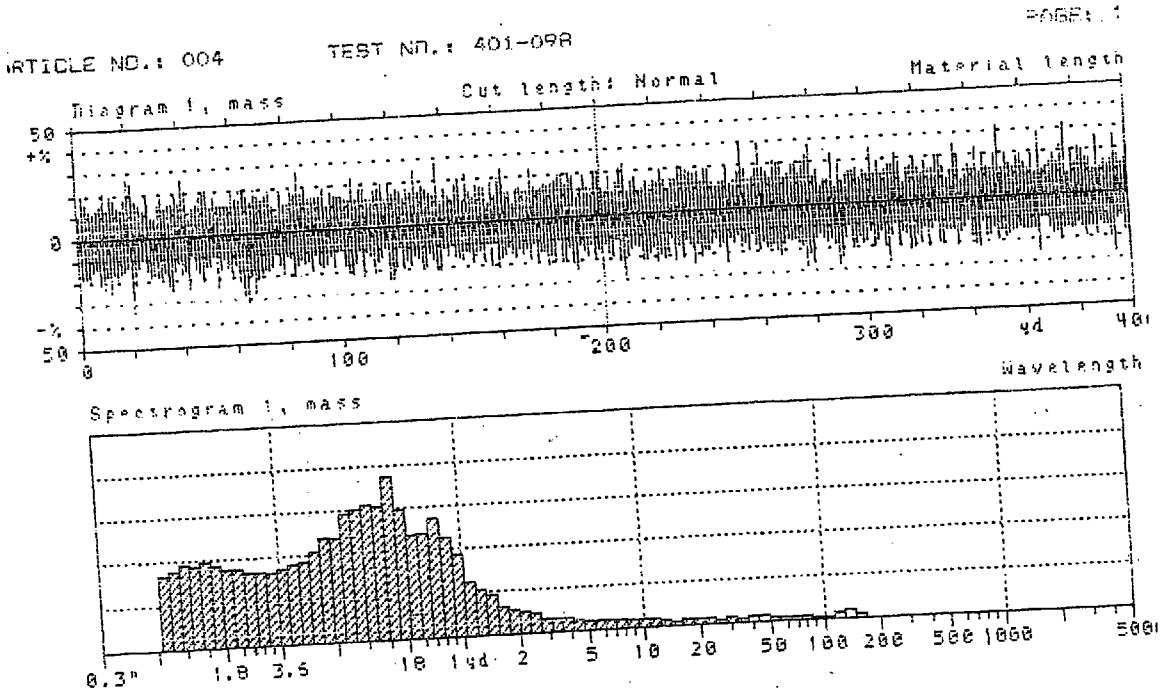
Figure 2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Spectrogram 1, mass
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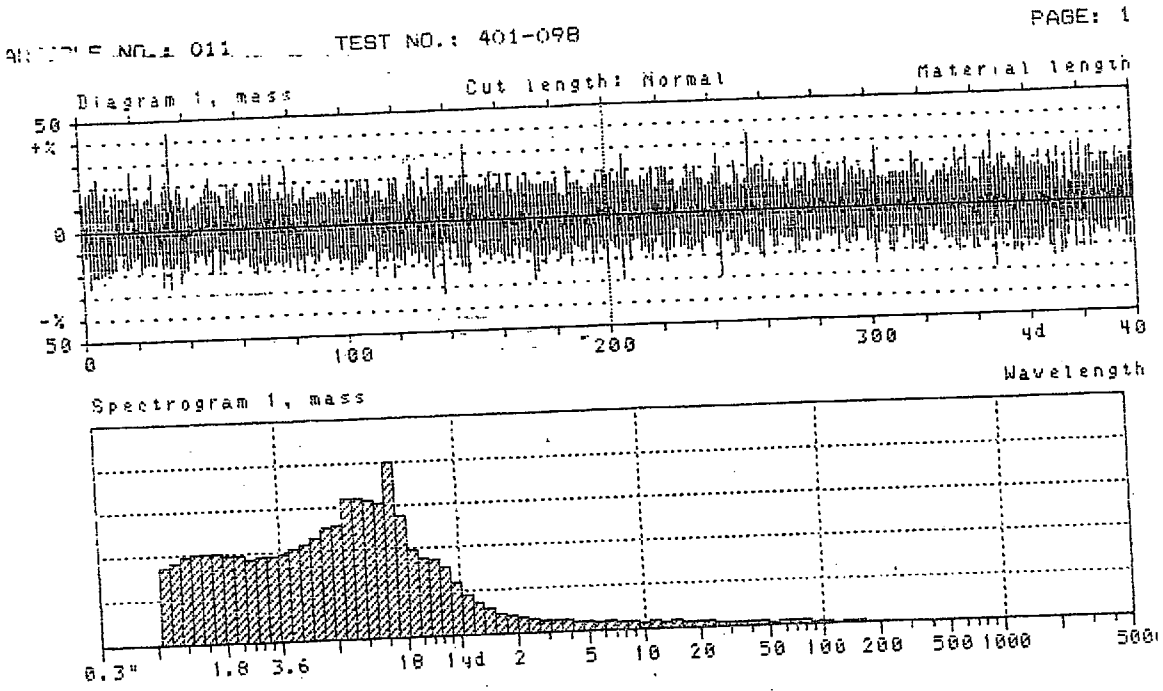
3.6
18
1yd
2
5
10
20
50
100
200
500
1000
5000

Figure 3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-%
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yd
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Spectrogram 1, mass
Wavelength
0.3"
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18
1yd
2
5
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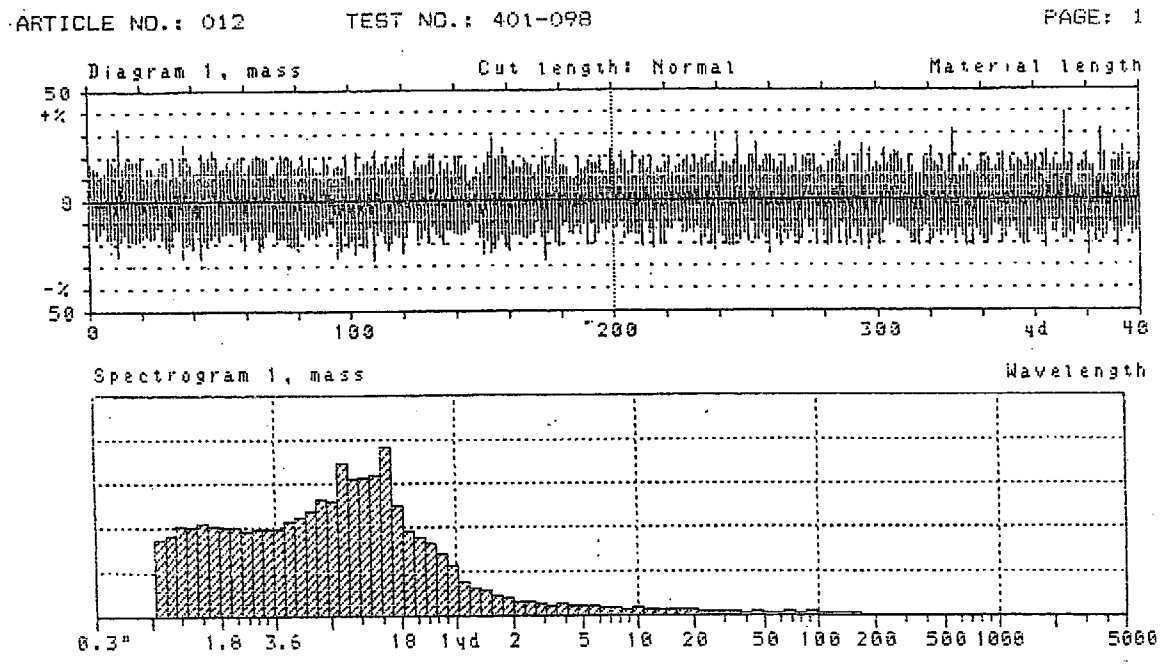
20
50
100
200
500
1000
500

Figure 4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300
yd
40
Spectrogram 1, mass
Wavelength
0.3"
1.8
3.6
18
1yd
2
5
10
20
50
100
200
500
1000
5000

Figure 5

Figure 6- drive roll with one or two nip rolls

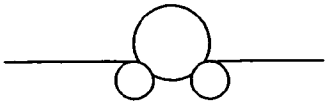


Figure 7 - drive roll with idler roll and multiple fiber wraps around rolls

Figure 8 - multiple roll set with serpentine fiber path

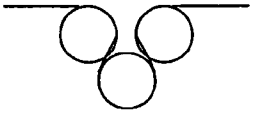
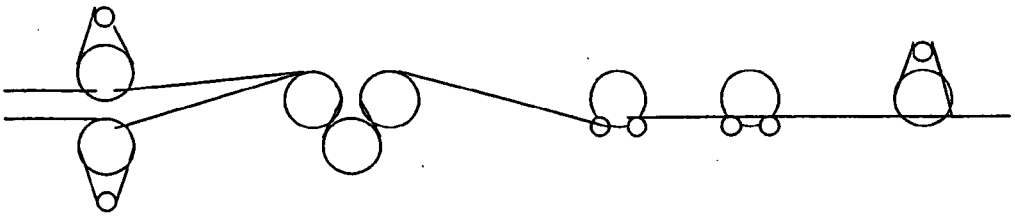


Figure 9 - Additional feed roll



STAPLE YARN MANUFACTURING PROCESS

[0001] This application claims the benefit of U.S. Provisional Application No. 60/645,695, filed Jan. 21, 2005, which is incorporated in its entirety as a part hereof for all purposes.

TECHNICAL FIELD

[0002] This invention relates generally to a fiber conversion and spinning process, and more particularly concerns methods for stretch breaking filament yarn to form staple fibers, and consolidating these fibers into a staple yarn. The process comprises a drawing step, followed by a tension control step, followed by a stretch breaking step, and, finally, a consolidation step. The invention also relates to an apparatus for performing such a process, and the yarn produced thereby.

BACKGROUND

[0003] Spun yarns have been produced from continuous filaments prepared from synthetic materials such as polymers by cutting the continuous filaments into staple fibers, which are then assembled into yarn in the same manner as natural fibers of cotton or wool.

[0004] Another method of producing yarn from staple fibers is by stretch-breaking continuous filaments to form staple fibers. This method is further divided into two groups. In a first group, large tows of filaments are stretch-broken to form heavy slivers of staple fibers, as described for example in U.S. Pat. No. 4,924,556 (Gilhaus). These slivers are then processed into yarns via conventional systems also used for cotton or wool. Because the staple fibers obtained from the stretch-broken filaments are processed on conventional yarn manufacturing machinery, the average fiber length, and fiber length distribution, must be tightly controlled. Multiple stretch-break zones are taught by Gilhaus for progressively reducing the fiber lengths to accomplish this task. In a second group, smaller tows are stretch broken to form small slivers that are then spun directly into yarns, as described for example in U.S. Pat. No. 2,721,440 (New) or U.S. Pat. No. 2,784,458 (Preston). Methods of this second group are sometimes referred to as direct spinning.

[0005] Such early processes were slow due to the inherent speed limitations of a true twisting device. As an alternative to true twisting, U.S. Pat. No. 3,110,151 (Bunting) discloses consolidating staple fibers to make a yarn product using an entangling, or interlacing, jet device. Such a product can be produced faster than true twisting, but is not comparable to conventional spun yarns in strength, cleanness and uniformity.

[0006] Alternatively, U.S. Pat. No. 4,080,778 (Adams) discloses a process where a 1500-5000 denier tow of continuous filaments may be heated and drawn, and is then stretch-broken and drafted in a single zone and exits at high speed through an apertured draft roll and an aspirator to maintain co-current flow of fluid and fiber through the roll nip. A roll-speed ratio of at least 5 in the stretch breaking zone is required by Adams to have process stability and good quality yarn. The discontinuous, unconsolidated filaments are then consolidated in an entangling jet of a type disclosed in Bunting to make a yarn of 50-300 denier. Because there is no requirement for further yarn processing, fiber length restrictions are not present. In Adams, about 1.5-20% of the discontinuous-filament fibers produced in the stretch-breaking zone exceed 76 cm in length, and about 50 to 93.5% of the fibers are 12.7 to 76 cm long. The yarn axis is required to be vertical throughout the process. The resultant product is a consolidated yarn with excellent strength, generally higher than ring-spun yarns, which is slub-free and clean.

[0007] A horizontal in-line process for making a fasciated yarn from a tow of fibers is taught by in U.S. Pat. No. 4,667,463 (Minorikawa). The process involves drawing the tow over a heater in an elongated area having a narrow width, draft cutting the tow, and subjecting the draft-cut fibers to an amendatory draft cutting step and a yarn formation step. The length of the zone in the amendatory draft cutting step is about 0.4 to 0.9 times the length of the draft cutting zone, and the roll-speed ratio for the amendatory draft cutting is at least 2.5. The drawing preferably occurs in two stages to achieve a draw ratio of 90-99% of the maximum draw ratio, and the drawn fiber is then heat treated. The yarn formation step uses a jet system for consolidating the fibers by creating wrapper fibers around the fiber core and wrapping them around the core fibers. Occasionally, apron bands are used in the amendatory draft cutting zone and yarn formation zone to regulate the peripheral fibers. The product is described in U.S. Pat. No. 4,356,690 (Minorikawa) with reference to the fact that more than about 15% of the discontinuous filaments in the fibers of the yarn have a filament length of less than 0.5 times the average filament length, and more than about 15% of the filaments in the fibers of the yarn have a filament length greater than 1.5 times the average filament length, where the preferred average filament length is between 50 and 500 mm. In the examples shown, the maximum output speed of the process, making yarns of 174 to 532 denier (30.5 to 10 cotton count), is 200 meters/minute (Example 6) with most examples run at about 100 meters/minute.

[0008] In the products of the Adams process, the long average fiber length, and the fact that 1.5 to 20% of fibers exceed 76 cm, limit the number of fiber ends that are available to protrude from the yarn and provide a yarn with a comfortable feel and look for many textile applications. Adams requires these long fibers in order to achieve a stable process and good yarn quality.

[0009] In contrast to the Adams process, both Gilhaus and Minorikawa require at least two breaking zones to achieve the desired average fiber length and fiber length distribution. Long breaking zones have been thought to be required for process stability and clean yarns while short breaking zones have been thought to be required for short fiber lengths. When a short breaking zone is used, the average fiber length is typically about 0.5 the length of the shortest breaking zone, with a range of the average fiber length being about 0.4 to 0.7 times the length of the shortest breaking zone.

[0010] WO 00/77283 (Popper) discloses a stretch-break method in which the yarn produced has a weight average fiber length of greater than six inches.

[0011] A need thus remains for a direct spinning process for producing a stretch-broken yarn with an average fiber length sufficiently short to result in aesthetics similar to conventional staple-fiber yarns. There is also a need for a process that can operate robustly and at a high speed (for

example, above 250 m/min) to make the production of yarn directly from a small tow or creel in a single line economically attractive.

[0012] The existing one-break-zone processes also appear to produce yarns having unacceptable mass uniformity. In particular, mass variations in yarn lengths of 2 meters to 10 meters may be such that fabrics appear to have thick and thin places despite a measured mass uniformity (CV %) that is well within the normally accepted range. The process of the present invention overcomes these problems.

SUMMARY

[0013] One embodiment of this invention is a process for making a staple yarn from a filament yarn by

[0014] (a) subjecting the filament yarn to an amount of tension at which filaments in the yarn are drawn,

[0015] (b) subjecting the yarn to an amount of tension at which the filaments in the yarn are not further drawn and are not broken,

[0016] (c) subjecting the yarn to an amount of tension at which filaments in the yarn are broken to form staple fibers, and

[0017] (d) consolidating the staple fibers to form a staple yarn.

[0018] Another embodiment of this invention is a process for making a staple yarn from a filament yarn by

[0019] (a) passing the filament yarn into a draw zone of a spinning apparatus wherein the yarn is subjected to an amount of tension at which filaments in the yarn are drawn,

[0020] **1**(b) passing the yarn out of the draw zone into a tension control zone of the apparatus wherein the yarn is subjected to an amount of tension at which filaments in the yarn are not further drawn and are not broken,

[0021] (c) passing the yarn out of the tension control zone into a stretch-break zone of the apparatus wherein the yarn is subjected to an amount of tension at which filaments in the yarn are broken to form staple fibers, and

[0022] (d) passing the staple fibers out of the stretch-break zone into a consolidation zone of the apparatus wherein the staple fibers are consolidated to form a staple yarn.

[0023] A further embodiment of this invention is a spinning apparatus for making a staple yarn from filament yarn that includes

[0024] (a) a draw zone wherein the yarn is subjected to an amount of tension at which filaments in the yarn are drawn,

[0025] (b) a tension control zone, into which the filament yarn is passed from the draw zone, wherein the yarn is subjected to an amount of tension at which the filaments in the yarn are not further drawn and are not broken,

[0026] (c) a stretch-break zone, into which the filament yarn is passed from the tension control zone, wherein the yarn is subjected to an amount of tension at which filaments in the yarn are broken to form staple fibers, and

[0027] (d) a consolidating zone, into which the staple fibers are passed from the stretch-break zone, wherein the staple fibers are consolidated to form a staple yarn.

[0028] Yet another embodiment of this invention is a staple yarn that includes staple fibers wherein the staple fibers have a weight average fiber length of less than about 6 inches, and a fiber length distribution in the range of from less than 1 inch to about 25 inches.

DESCRIPTION OF THE DRAWINGS

[0029] Other features of the present invention will become apparent from the following description and upon reference to the drawings, in which:

[0030] **FIG. 1** is a side elevation view of an apparatus of this invention, which may be used to run the process of this invention and which includes a draw zone, a tension control zone, a stretch-breaking zone and a consolidation zone.

[0031] FIGS. **2**~**5** show mass uniformity spectrograms obtained on the yarns produced in Examples 1~4.

[0032] FIGS. **6**~**8** illustrate alternative godet arrangements that can be used in the process of this invention.

[0033] **FIG. 9** is an illustration of an embodiment that includes a second set of feed rolls in order to draw different feed materials that have different draw ratios.

DETAILED DESCRIPTION

[0034] A process has been developed that produces, from a feed of filament yarn, a staple yarn in which the staple fibers therein have a weight average fiber length of less than about six inches (6"), resulting in a desirably high number of fiber ends per inch. This process is able to provide these relatively short weight average fiber lengths using an apparatus that does not employ a short stretch-breaking zone because the ratio of the weight average fiber length to the length of the stretch-breaking zone can be controlled to be less than about 0.4. This process operates at rates that greatly exceed those at which ring-spun staple yarns are made. The process permits operation in either a vertical or horizontal orientation without sacrificing production speed or efficiency. The process is adaptable to using, as the feed, filament yarns made from a variety of materials, including a variety of polymers.

[0035] Various improvements to conventional stretch-break processes are disclosed including using a tension control zone to eliminate or control the stresses in the filaments in the feed yarn prior to stretch-breaking. This tension control results in the ability to greatly influence the location at which the filaments in the feed yarn break in the stretch-breaking zone, and therefore to change the fiber length distribution, primarily the weight average fiber length, of the staple fibers produced by stretch-breaking the continuous filaments in the feed yarn.

[0036] In preferred embodiments, the process utilizes the following zones in direct sequence, moving in an upstream-to-downstream direction: a draw zone, a tension control zone, a stretch-breaking zone, and a consolidation zone for

consolidating the staple fibers made up of discontinuous filaments, and intermingling them by any of a variety of means to produce and maintain unity in the yarn product. The process includes improvements to systems having one or more stretch break zones.

[0037] In further embodiments, an annealing zone is employed when it is desired to heat the filaments in the feed yarn and/or the staple fibers in the product yarn, and control product features such as shrinkage. An annealing zone is most often part of the draw zone, but may be applied at a variety of locations in the process, including after the consolidation zone.

[0038] A fiber is a cylindrical-shaped unit of matter characterized by a length at least 100-times its diameter or width that is capable of being spun into a yarn, or made into a fabric, by various methods such as weaving, knitting, braiding, felting and twisting. For processing on textile machinery, a fiber of the correct length (such as about 1~8 inches) is needed. A staple fiber has the correct length for such purpose because it is either a natural fiber (e.g. from cotton or wool), and inherently has a useful length, or it is a bundle of discontinuous lengths of synthetic filaments that have been cut or broken from continuous filaments to the correct machine length. A bundle of continuous filaments, referred to herein as a filament yarn, is thus converted to staple fibers by being processed, for example, on stretch-breaking machine for the purpose of repeatedly breaking the continuous filaments at locations that produce discontinuous lengths of filament of a length suitable for consolidation into staple fibers.

[0039] A staple yarn, as contrasted with the filament yarn described above, is a continuous strand of staple fibers in a form in which the fibers are consolidated, and thus sufficiently intermingled that the yarn has an integrity and unity of construction along the length of the yarn suitable for knitting, weaving, or otherwise intertwining, to form a fabric. A staple yarn may also contain continuous, unbroken filaments that have been incorporated into the stream of broken filaments from which the staple fibers, and ultimately the staple yarn, are produced.

[0040] The process of this invention produces a yarn constituted of staple fibers that have a shorter weight average fiber length than a yarn produced by a stretch-breaking system without a tension control zone, and does so with only one or two stretch-breaking zones. The staple yarn product of this invention is characterized by the presence of staple fibers of different lengths, the fibers being intermingled along the length of the yarn to maintain the unity of the yarn, wherein the weight average length of the fibers is less than 6 inches, and wherein the yarn has a fiber length distribution ranging from less than 1 inch to about 25 inches. Other products include the combination of continuous filaments with the staple fibers in the yarn product, the continuous filaments being added to the fibers, for example, after the stretch-breaking zone and at the entrance to the consolidation zone.

[0041] Referring now to the drawings, **FIG. 1** shows a direct spinning apparatus of this invention, on which the process of this invention may be performed. The filament yarn feed material for the process of this invention may come from a wound package of continuous filaments, or may come from a container of piddled continuous filaments from which the feed yarn may be freely withdrawn. The process of this invention can economically operate with a relatively small denier piddled feed yarn, which eliminates a costly winding step and permits the use of undrawn filaments that are sometimes difficult to wind in a package successfully. The filaments in the feed of the filament yarn may thus be undrawn before being fed to the draw zone of the apparatus, or may have previously been partially drawn or oriented. Feed material in either of these forms provides economical alternatives. This is in contrast to a sliver stretch-breaking device such as that disclosed in Gilhaus.

[0042] Filament yarn **1** is fed to the apparatus, and is first taken up between two sets of rolls **2** and **3**, which are driven at a predetermined speed by a conventional motor/gearbox and controller (not shown). Roll set **3** is driven at a higher rate of speed than roll set **2**, and the feed yarn is thus subjected, in this first zone **11** (the draw zone) to an amount of tension at which the filaments in the yarn are drawn.

[0043] A draw zone **11**, and drawing a filament yarn **1**, refers to stretching continuous filaments in a way that none, or substantially none, of the filaments are broken; the filaments remain continuous. Drawing a filament yarn may or may not include heating the filaments, and the draw zone **11** can thus optionally include a heater that may take many forms, and that may contact the filaments over a length that can easily be varied. The drawing of a filament may occur as soon as the filament is exposed to tension in the draw zone, and thus, for some polymers, drawing or elongation of the filament may occur just as the filament is leaving the upstream rolls **2**, or over a very short length such as an inch or less. In this case, a heater serves to anneal the drawn filament rather than heat it for drawing. For this type of filament, if draw heating is required, the rolls may be heated. Other polymers, however, may not draw until they experience some heat by contact with the surface of the heater, or may be drawn without heating at all. In still other cases, the draw zone may have a roll speed ratio that is not substantially in excess of one, the yarn will receive minimal drawing, and the draw zone would function as much as, or more as, an annealing zone than as a draw zone. The length of the draw zone **11** is not critical, and is primarily sized to accommodate the heating device when present.

[0044] The feed yarn **4**, in which the filaments have been drawn, is then passed out of the draw zone **11** and into a tension control zone **12**, which is located between roll sets **3** and **5**. Roll set **5** is driven at a speed, in relation to the speed of roll set **3**, at which the tension of the filaments in this zone is controlled to an amount that is selected to permit any residual stresses in the filaments to be dissipated. For this purpose, the rate of speed of roll set **5** may be less than, equal to or higher than the speed at which roll set **3** is driven. The amount of tension to which the filaments were subjected in the draw zone **11** is thus either reduced, maintained or increased in the tension control zone **12**. In all cases, however, the tension to which the filaments are subjected in the tension control zone is set at an amount at which the filaments in the feed yarn are not further drawn and are not broken. If the amount of tension to which the filaments are subjected in the tension control zone **12** is higher than the amount of tension to which they were subjected in the draw zone, this greater amount of tension will not be large enough to cause any further drawing in view of the temperature profile of the draw zone **11**, the mechanical properties of the

material from which the filaments are made, and the amount of drawing the filaments have already experienced in the draw zone **11**.

[**0045**] Although in the apparatus of this invention as shown in **FIG. 1**, the draw zone **11** feeds directly into, and is essentially part of the same machine as; the tension control zone **12**, the step of drawing yarn in a draw zone in the process of this invention need not be performed on the same machine as any of the other steps in the process.

[**0046**] The feed yarn **6** is then passed out of the tension control zone **12** and into a stretch-break zone **13**, which is located between roll sets **5** and **7**. The length of the stretch-break zone **13** is measured between the nip of roll set **5** and the nip of roll set **7**. The speed of the yarn **6** is increased within the stretch-break zone **13** by driving the yarn at a higher speed with roll set **7** than with roll set **5**. There should not be any slippage between the rolls and the yarn, thus the yarn speed and roll surface speed at the driven roll set **5** are the same, and the yarn speed and roll surface speed at the driven roll set **7** are the same. Increasing the speed of the yarn within the stretch-break zone **13** subjects the filaments in the yarn **6** to an amount of tension that causes the filaments to be stretched until the break elongation of the filament is exceeded, and the filaments, as gripped by both roll sets, will be broken. In the stretch-break zone **13**, to break the filaments, the ratio of the speeds of the roll sets should be such that the maximum imposed strain on the filaments exceeds the elongation to break of the material from which the filaments are made. Under such conditions, all or substantially all of the filaments will be broken in the stretch-break zone **13** to form staple fibers.

[**0047**] In addition to breaking continuous filaments in the feed yarn by running them at a high speed ratio and subjecting them to a tension that exceeds their elongation to break, filaments may also be broken by cutting or weakening them with a device such as a cut-converter or breaker bar [as described, for example in New or U.S. Pat. No. 4,547,933 (Lauterbach)], which reduces the breaking forces imposed at the nip rolls and controls some of the randomness of the breaking position in the filaments.

[**0048**] To achieve a practical breaking of filaments in a feed yarn in a single stretch-break zone **13**, the steady state tension required for breaking decreases as the ratio of the speed of the exit rolls **7** to the speed of the inlet rolls **5** increases. If a yarn enters the stretch-break zone **13** under high tension, the filaments therein are more likely to break closer to the inlet rolls **5**. A break closer to the inlet rolls **5** will cause a longer weight average fiber length in the staple fibers formed from the broken, discontinuous filaments, which may for example be a weight average length of greater than about 0.5 times the length of the stretch-break zone **13**. If a yarn enters the stretch-break zone **13** under low tension, the filaments therein are more likely to break closer to the exit rolls **7**. A break closer to the exit rolls **7** will cause a shorter weight average fiber length in the staple fibers formed from the broken, discontinuous filaments, which may for example be a weight average length of less than about 0.5 times the length of the stretch-break zone **13**. This phenomenon can be used to create staple fibers with a weight average length of less than about 6" without the necessity of decreasing the length of the stretch-break zone used, thereby maintaining good operability and yarn quality. In the stretch-breaking of yarns, a shorter break zone results in shorter fibers, but a longer break zone is required for good operability and yarn quality.

[**0049**] Tension on a yarn is measured in grams and may be determined by use of a tensiometer. The tension on the yarn, and thus on the filaments therein, in the draw zone, tension control zone and the stretch-break zone, may be determined from the mass flow, the break elongation and the break strength of the yarn.

[**0050**] After the continuous filaments in the feed yarn are broken, the assembly of discontinuous filaments, from which staple fibers are formed, may also be drafted in the stretch-break zone to reduce denier as its speed continues increasing until it reaches the speed of the roll set **7**. The same phenomenon mentioned above allows the draft within the stretch-break zone to be operated over a wide range of roll speed ratios, even less than 5, and enables use of feed creels with a relatively small number of packages of feed yarn of continuous filaments instead of having to create a very large feed tow from many packages.

[**0051**] Staple fibers **8**, as formed from the broken, discontinuous filaments, are passed out of the stretch-break zone **13** and into a consolidation zone **14** between roll sets **7** and **9**. The fiber speed can be decreased slightly within the consolidation zone **14**, but there should not be any slippage between the rolls and the fibers, and thus the fiber speed and roll surface speed at the driven roll set **7** are the same, and the fiber speed and roll surface speed at the driven roll set **9** are the same. In other cases, it may be desired to increase the fiber speed within the consolidation zone by a small amount to improve the entanglement of the fibers. In this case, some drafting would occur. One or more consolidation devices **10**, such as an aspirator jet or an interlace jet, are located in the consolidation zone. An interlace jet interconnects the fibers by entangling them with one another to form a staple yarn, and, in doing so, it can slightly shorten the length of the fibers as the yarn is formed, which accounts for the decreased speed in the consolidation zone. An appropriate interlace jet is described, for example, in U.S. Pat. No. 6,052,878 (Allred), in WO 03/29539 (Buchmuller), or in the Heberlein interlacing jet catalogs. Other suitable fiber interconnecting jets are described, for example, in U.S. Pat. No. 4,825,633 (Artzt) and in the Murata Jet Spinner catalog. The staple fibers, after passing through the consolidation device, become a consolidated staple yarn having good cohesiveness and strength.

[**0052**] If desired, an annealing zone (not shown) can be added after the consolidation zone **14**. The annealing zone may, for example, be operated in the same manner as discussed above where the draw zone **11** is operated with heating means but with an extremely small speed ratio. This may be useful in a process where the final shrinkage of the yarn product must be controlled to a specified value, and annealing after formation of the yarn is the most direct way to accomplish this. It may also be useful when the feed yarn is prepared from two different materials, and the annealing heat treatment causes each material in the yarn product to respond differently to create a special effect in the yarn, as, for example, when the shrinkages of the fibers are different and the differential shrinkage produces a bulky or loopy yarn. In alternative embodiments, there may be a small overfeed of the fiber into the annealing zone.

[0053] In other alternative embodiments, the godet arrangements shown in FIGS. **6~8** can be used in the process and apparatus of this invention. These alternative arrangements illustrate means to assure adequate friction between the godets and the yarn, thereby eliminating slippage. **FIG. 8** illustrates a means to process two different feed yarns requiring different draw ratios.

[0054] Following roll set **9** the consolidated staple yarn is directed to a winder. The consolidated yarn produced by the process may be wound into a package or piddled into a container for transfer to another process or for shipping; or passed on to other machine elements for further processing.

[0055] The feed yarn that is used in the process of this invention may be pre-treated such as by the application of a finish, or by a structural manipulation such as crimping with jets, gear crimpers or a stuffer box. Selection of any finish used on the feed yarn is, however, a consideration for operability. If too much finish is used, independent filament mobility and breaking in the stretch-break zone is adversely affected. If too little finish is used, static becomes a problem, and roll wraps are increased. A finish level of less than about 0.1 wt % is preferred, and less than about 0.04 wt % is more preferred, by weight of the material from which the filaments are made. A typical finish composition may include an ethylene oxide condensate of a fatty acid, an ethoxylated or propoxylated alcohol capped with pelargonic acid, the potassium salt of a phosphate acid ester, and/or the amine salt of a phosphate acid ester. Other finishes that may be useful for filaments to be stretch broken are described, for example, in Adams and in JP 58(1983)-44787 (Hirose).

[0056] The staple yarn product of this invention is prepared from consolidated staple fibers of discontinuous filaments of different lengths, the fibers being intermingled along the length of the yarn to maintain the integrity and unity of the yarn. The yarn product has a denier that can be readily used in textile applications without further preparation other than conventional dyeing or the like. The linear density of the yarn product is typically less than or equal to about 1000 denier. Alternatively, however, the yarn product may have a linear density of greater than about 1000 denier, and the fibers from which the yarn is made may have in such case a total of about 500 or fewer filaments in a cross-section of the yarn. In a preferred embodiment, the staples fibers in the yarn product have a weight average fiber length of less than about 6 inches, and they have a fiber length distribution wherein the fibers range from a minimum of less than 1 inch to a maximum of about 25 inches. The maximum length of about 99% of the fibers is less than about 25 inches, and more than about 50% of fibers have a length that is in the range of about 0.5 to about 1.5 times the weight average length fiber. The number average fiber length is also less than about 6 inches. The yarn product has a useful number of fiber ends per inch, and a substantial percentage of these fiber ends can be found as protruding ends extending from the central portion of the yarn to give the yarn a desirable feel or "hand".

[0057] In making the yarn product of this invention, two or more different kinds of feed yarns may be used. In one embodiment, different feed yarns would go through the draw, tension control, stretch-break and consolidation zones together. The different yarns could be combined together into a single yarn before being fed into the apparatus, or could simply be fed separately but simultaneously.

[0058] In another embodiment, however, the yarn of this invention may be made by introducing one or more additional feed yarns at the downstream end of the draw zone or at the downstream end of the tension control zone. This is a useful approach if filament yarns that do not require drawing are to be added to yarns that do need to be drawn. All yarns would be broken at the same time in the stretch-break zone, and would continue to be treated together throughout the remainder of the process.

[0059] In a further embodiment, the yarn product of this invention may be made by introducing a first additional feed yarn(s) at the downstream end of the draw zone or the downstream end of the tension control zone, and by introducing a second additional feed yarn(s) at the upstream end of the consolidation zone. In this embodiment, the first additional feed yarn(s) would pass through the stretch-break zone, and thus be broken into discontinuous filaments, but the second feed yarn(s) would not pass through the stretch-break zone. As a result, the second feed yarn(s) could be a filament yarn as to which it is intended that the filaments remain continuous and thus unbroken, and/or the second feed yarn(s) could be a previously-prepared staple yarn that already incorporates staple fibers. In yet another embodiment, one or more additional feed yarns may be introduced only at the upstream end of the consolidation zone.

[0060] Where there are differences between feed yarns, the differences may, for example, be in denier per filament where one yarn has a denier per filament (dpf) of less than about 0.9, and the other yarn has a denier per filament of greater than about 1.5. The advantage of making the yarn product from two or more yarns having a difference in dpf is that the structural stiffness of the yarn product can be determined by the larger dpf feed yarn while the softness can be controlled by the smaller dpf feed yarn. This overcomes some problems with small dpf yarns that have a good hand but are too limp when made into fabric.

[0061] When different feed yarns are used, the elongation to break of each should be similar for desirable performance in the draw zone. If the different yarns do not have similar elongation to break, one of them could be partially pre-drawn to be compatible with the other. Alternatively, a second, independent set of feed rolls (**2**A) could be installed in the apparatus, as shown in **FIG. 9**, that operate at a speed different than roll set **2** so that the different yarns could be drawn at different speed ratios while still being joined together at the draw rolls **3**.

[0062] Where different feed yarns are used in this invention, they may contain filaments prepared from different polymers, such as two different nylon polymers, two different polyesters, or a nylon polymer and a polyester. Different polymers as used in the feed yarn should be compatible so that they stick together and can be cospun. For this purpose, they should have a similar thermal response and functional spinning viscosity, or have some specific interaction such as a chemical interaction. In a further embodiment, feed yarns having filaments with different structures may also be used, such as a bicomponent and/or biconstituent filament. A bicomponent filament has one or more distinct structural domains or regimes such as a sheath/core structure, whereas a biconstitutent filament is characterized by a much more intimate blend of the polymers from which the filament is made without discernable structural domains or domains

that have any substantial functional effect. The weight percent ratio at which different polymers may be used in the feed yarn(s) may vary considerably, but is generally between about 80/20 and about 20/80, and preferably about 70/30 to about 30/70.

[0063] A bicomponent filament in a feed yarn may be made, for example, from a core polymer that is highly elastic (or "soft"), such as a Lycra® elastomer, and from an inelastic ("hard") polymer that is attached as "wings" or longitudinal ribs during the spinning process. After spinning, the latent elasticity of the filament can be activated by heat that causes the soft core polymer to shrink considerably more than the hard "wing" polymer, and this causes the composite structure to coil helically, giving it the appearance and structure of a screw thread. This filament structure also has some crimp after spinning and drawing and before heat treating.

[0064] Other combinations of polymers from which a bicomponent or biconstituent filament in a feed yarn may be made include a 4GT/4GT-4GO polyester (such as HYTREL® polyester from DuPont) and nylon/PEBAX® polymer (from DuPont); or a homopolymer/block copolymer pair in which one block of the copolymer is the same as the homopolymer.

[0065] Differences in feed yarns as used in this invention may involve differences other than or in addition to differences in choice of polymer, such as differences in color or differences in a surface treatment that gives the yarn some other visual characteristic that can be detected with the unaided eye, such as differences in the reflectance, absorbence or wettability of the yarns. The process of this invention provides a useful way to make specialty yarns characterized by visual effect without involving numerous steps, such as is required in the conventional blending of staple fibers where a sliver must first be prepared by chopping (cutting), blending, carding, combing and the like. In the conventional system, a large quantity of feed fiber must be prepared to make the process worthwhile, since cleaning the processing equipment after each product run is very labor intensive and time consuming. In the process of this invention, however, a color-blended yarn product, for example, that has a different color than either of the feed yarns, may be made on a much smaller scale as there is practically no cleanup required to switch to another feed blend other than changing packages in a creel.

[0066] The differences in color between different feed yarns as used in this invention may include, for example, two colors that are essentially non-white and non-beige variations, although one yarn may have a color that is a white or beige, and the other yarn may have a color that is a distinctly non-white, non-beige color. The different colors of the feed yarns will be selected such that the combination of the two in the yarn product achieves a new color that is distinctly different from either of the feeds. Differences in color may be determined and describe according to ASTM Sandard E-284-05a, Committee E12.01, 2005, which describes a means to distinguish neutral colors, such as white and beige, based on a lightness measurement with white and beige having a lightness greater than 90%. It also permits distinguishing color hue and shade to detect color difference by using CIELAB units where different colors as used herein would have a CIELAB unit difference of at least 2.0. Blending two or more yarns having different colors where only one yarn has a lightness greater than 90%, and the yarns have a color difference in CIELAB units of at least 2.0, creates a yarn having a new color that is suitably different from the colors of either feed yarn. When the yarn product is fabricated further into a textile or fabric, the blended color has a mild heather appearance.

[0067] When an additional feed yarn is introduced at the downstream end of the draw zone or at the downstream end of the tension control zone, to be broken in the stretch-break zone along with the primary feed yarn, the primary feed yarn and/or the additional feed yarn may be prepared from any one or more polymers selected from the group consisting of nylon, polyester, an aramid, a fluoropolymer, an acetate polymer or copolymer, an acrylic polymer or copolymer, polyacetal, an acrylate polymer or copolymer, polyacrylonitrile, a cellulose polymer, an olefin polymer or copolymer, polyimide, a styrenic polymer or copolymer, an ether/ester copolymer, a copolymer of an amide with an ether and/or ester, a vinyl polymer, and a polyimide. For example, the additional feed yarn may be prepared from one or more polymers selected from the group consisting of aramid polymers and fluoropolymers, and that additional feed yarn may be added to a primary feed yarn that is prepared from one or more polymers selected from the group consisting of nylon, polypropylene and polyester.

[0068] As noted above, when an additional feed yarn is introduced at the upstream end of the consolidation zone, it is not subjected to any stretch-breaking. If that yarn contains any continuous filaments, they will retain their continuous character. A feed yarn added at the upstream end of the consolidation zone may be prepared from any one or more polymers selected from the group consisting of nylon, polyester, an aramid, a fluoropolymer, an acetate polymer or copolymer, an acrylic polymer or copolymer, polyacetal, an acrylate polymer or copolymer, polyacrylonitrile, a cellulose polymer, an olefin polymer or copolymer, polyimide, a styrenic polymer or copolymer, an ether/ester copolymer, a copolymer of an amide with an ether and/or ester, a vinyl polymer, a polyimide, a polyurethane, a copolymer having blocks of polyurethane and blocks of polymerized ethers and/or esters, a natural fiber, a metallic fiber or wire (e.g. copper or steel), a glass fiber, and a ceramic fiber. It is preferred but not required that a yarn added at the upstream end of the consolidation zone be prepared from a different material than a yarn added at any other stage of the process. For example, a yarn added at the upstream end of the consolidation zone may be prepared from an elastane or spandex-type filament, a Lycra® elastic polymer, high strength filaments with low elasticity such as those made from an aramid polymer, or filaments with high elasticity such as those made from a 2GT [1,2-ethane diol (or ethylene glycol) esterified with terephthalic acid] or a 3GT [1,3-propanediol (or 1,3 propylene glycol) esterified with terephthalic acid] polyester. Filaments, when made from a spandex-type polymer, preferably have an elongation to break greater than about 100% and an elastic recovery of at least 30% from an extension of about 50%. These additional feed yarns can be added to a primary feed yarn that is prepared from a polymer such as nylon, polyester, polypropylene, a fluoropolymer or an aramid polymer such as a Nomex® polymer [a polymer made from isophthaloyl chloride and methylphenylene diamine (from DuPont)] or a Kevlar®

polymer [a polymer made from terephthaloyl chloride and methylphenylene diamine (from DuPont)].

EXAMPLES

[0069] The advantageous effects of this invention are demonstrated by a series of examples, as described below. The embodiments of the invention on which the examples are based are illustrative only, and do not limit the scope of the appended claims.

[0070] A test for uniformity, in terms of evenness and frequently occurring yarn faults, were performed using a standard Uster UT-3 yarn testing instrument (Uster Technologies AG, Zellweger Uster, Uster Switzerland), per the methods recommended by the manufacturer, on four samples of staple yarns (Examples 1~4) prepared according to the process of this invention. In the uniformity test, the yarn is passed between two parallel capacitor plates, and variations in the mass of the yarn cause a change in the dielectric of the air between the plates, causing a proportional change in the electric signal from the sensor. Tests of yarn strength were also performed on the same yarn samples using an Uster TensoJet.

[0071] The yarns of Examples 1~4 as tested herein were each made from three feed packages of partially drawn polyester filament yarns wherein each filament had a denier of 255 and each yarn contained approximately 200 filaments. The feed yarns were used to produce a staple yarn product on an apparatus of this invention having a stretch-break zone length of about 16 inches. Operating conditions by which each staple yarn was made are outlined in Table I.

[0072] The result of the yarn uniformity test are shown in Table II, the results of the yarn strength test are shown in Table III, and the mass uniformity spectrogram for the yarns of Examples 1~4 are shown, respectively, in FIGS. **2**~**5**. In Table II, CVm is the coefficient of mass variation, which expresses the amount of variation in the yarn around a mean value of the mass. It is obtained by dividing the standard deviation by the mean and multiplying by 100, and is expressed as a percentage deviation from the mean. In Table II, the count of 50% thin places, locations where the mass of the yarn decreases by 50% or more from the mean yarn mass, and the count of 50% thick places, locations where the mass of the yarn increases by 50% or more from the mean yarn mass, are set forth; as is the count of 280% Neps, locations where the mass of the yarn increases by 280% or more from the mean yarn mass. In Tables II and III, yarn count is expressed in terms of Nec, Number English Cotton, which is the number of 840 yard lengths in the yarn per pound. In Table III, tex is the number of grams in a kilometer of yarn.

TABLE I

Example	Roll Speed Ratio in Draw Zone	Draw Roll Temperature (° C.)	Tension Control Ratio	Stretch Break Zone Ratio	Consolidation Zone Ratio	Output Speed (m/min)
1	2.0	220	1.02	2.20	1.01	703
2	2.0	220	1.00	2.20	1.01	703
3	2.0	220	0.995	2.20	1.01	703
4	2.0	220	0.990	2.20	1.01	703

[0073]

TABLE II

Yarn Evenness as tested on Uster Tester 3					
Example	CVm (%)	Final Yarn Count (Nec)	Thin Places (−50% per 1000 yds)	Thick Places (+50% per 1000 yds)	Neps (+280% per 1000 yds)
1	10.45	31.82	0	5	8
2	10.05	31.31	0	1	3
3	10.5	31.05	0	0	6
4	10.48	30.96	2	3	11

[0074]

TABLE III

Yarn Strength as tested on Uster TensoJet set to 500				
Example	Mean Count (Nec)	Mean Break Force (cN)	Mean Elongation (%)	Mean Tenacity (cN/tex)
1	31.82	376.4	5.27	20.28
2	31.31	351.0	5.33	18.61
3	31.05	333.3	5.35	17.52
4	30.96	330.0	5.40	17.3

[0075] The mass uniformity wavelength spectrogram for a yarn made from staple fibers of uniform length has a different appearance than that for a yarn made from fibers of varying, i.e. distributed, lengths. In either case, however, there is a well defined peak in the shape of the curve of the spectrogram, even for an ideal yarn of completely random fiber arrangement. The curve of the spectrogram for an ideal yarn can be mathematically determined from the fiber length distribution. Likewise, the peak of the curve has the mathematical relationship to the weight average fiber length of 2.7 times the weight average fiber length for a yarn comprised of fibers of equal length; and approximately 2.8 times the weight average fiber length of a yarn comprised of fibers of unequal, or distributed, lengths. These mathematical relationships can be used to quickly and easily determine the weight average fiber length of any staple yarn, thereby eliminating the need for difficult and time-consuming measurements of individual fibers within the yarn.

[0076] **FIGS. 2 through 5** show the spectrograms of various polyester yarns made in accordance with the invention. It can be seen that the major peak of each of the curves are all less than about 16 inches. From the mathematical model, the weight average fiber length in these yarns may therefore be determined to be less than 6 inches. The spectrograms for Examples 1 and 2 have a slight depression at about 3.6 inches, which is an indication of a significant proportion of the fibers being about this length. By comparison, a conventional yarn of short staple fibers has a peak at less than 0.1 yards (3.6") because of the short fiber lengths of approximately 1 inch or less. Typical long staple fibers including wool or synthetic fibers made using a conventional multiple-zone stretch-break process such as described by Gilhaus, have a spectrogram peak of approximately 0.25 yards (9") which corresponds to an average fiber lengths of about 3 inches. Therefore, the shorter fibers in the yarns of this invention provide a large number of fiber ends in the

consolidated yarn when compared to yarns made with a single stretch breaking zone process without the benefit of a tension control zone.

[0077] It is therefore apparent that there has been provided, in accordance with the present invention, methods for stretch-breaking filament yarns (containing continuous filaments) to form staple fibers (containing discontinuous filaments), and consolidating these staple fibers into staple yarns, that fully satisfy the aims and advantages hereinbefore set forth. While this invention has been described in conjunction with a specific embodiment thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and scope of the appended claims.

[0078] Each patent or other publication mentioned above is incorporated in its entirety as a part hereof for all purposes.

What is claimed is:

1. A process for making a staple yarn from a filament yarn comprising

(a) subjecting the filament yarn to an amount of tension at which filaments in the yarn are drawn,

(b) subjecting the yarn to an amount of tension at which the filaments in the yarn are not further drawn and are not broken,

(c) subjecting the yarn to an amount of tension at which filaments in the yarn are broken to form staple fibers, and

(d) consolidating the staple fibers to form a staple yarn.

2. The process of claim 1 wherein the filament yarn has not been drawn before being drawn in step (a).

3. The process of claim 1 wherein the filament yarn has been partially drawn before being drawn in step (a).

4. The process of claim 1 wherein the filament yarn is prepared from one or more polymers selected from the group consisting of polyester, polyamide and polypropylene.

5. The process of claim 1 further comprising steps of adding continuous filaments and/or consolidated staple yarn to the staple fibers as formed from step (c), and consolidating the continuous filaments and/or consolidated staple yarn with the staple fibers to from a staple yarn in step (d).

6. The process of claim 5 wherein the consolidated staple yarn is prepared from one or more materials selected from the group consisting of polymers, metals, glass and natural fibers.

7. The process of claim 1 further comprising steps of adding fully-drawn filament yarn, as a second yarn, to the yarn that is drawn in step (a), as a first yarn, and subjecting both the first and second yarns to tension in step (b) together.

8. The process of claim 7 wherein the second yarn is prepared from one or more materials selected from the group consisting of polyester, polyamide, polypropylene, aramid, acetate and regenerated cellulose.

9. The process of claim 1 wherein, in step (b), the filament yarn is subjected to a smaller amount of tension than it is subjected to in step (a).

10. The process of claim 1 wherein, in step (b), the filament yarn is subjected to the same amount of tension that it is subjected to in step (a).

11. The process of claim 1 wherein, in step (b), the filament yarn is subjected to a greater amount of tension than it is subjected to in step (a).

12. A spinning apparatus for making a staple yarn from filament yarn comprising

(a) a draw zone wherein the yarn is subjected to an amount of tension at which filaments in the yarn are drawn,

(b) a tension control zone, into which the filament yarn is passed from the draw zone, wherein the yarn is subjected to an amount of tension at which the filaments in the yarn are not further drawn and are not broken,

(c) a stretch-break zone, into which the filament yarn is passed from the tension control zone, wherein the yarn is subjected to an amount of tension at which filaments in the yarn are broken to form staple fibers, and

(d) a consolidating zone, into which the staple fibers are passed from the stretch-break zone, wherein the staple fibers are consolidated to form a staple yarn.

13. A staple yarn comprising staple fibers wherein the staple fibers have a weight average fiber length of less than about 6 inches, and a fiber length distribution in the range of from less than 1 inch to about 25 inches.

14. The yarn of claim 13 wherein more than 50% of the staple fibers have a length that is in the range of about 0.5 to about 1.5 times the weight average fiber length.

15. The yarn of claim 13 further comprising continuous filaments.

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