

March 9, 1971

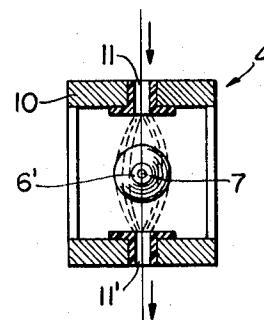
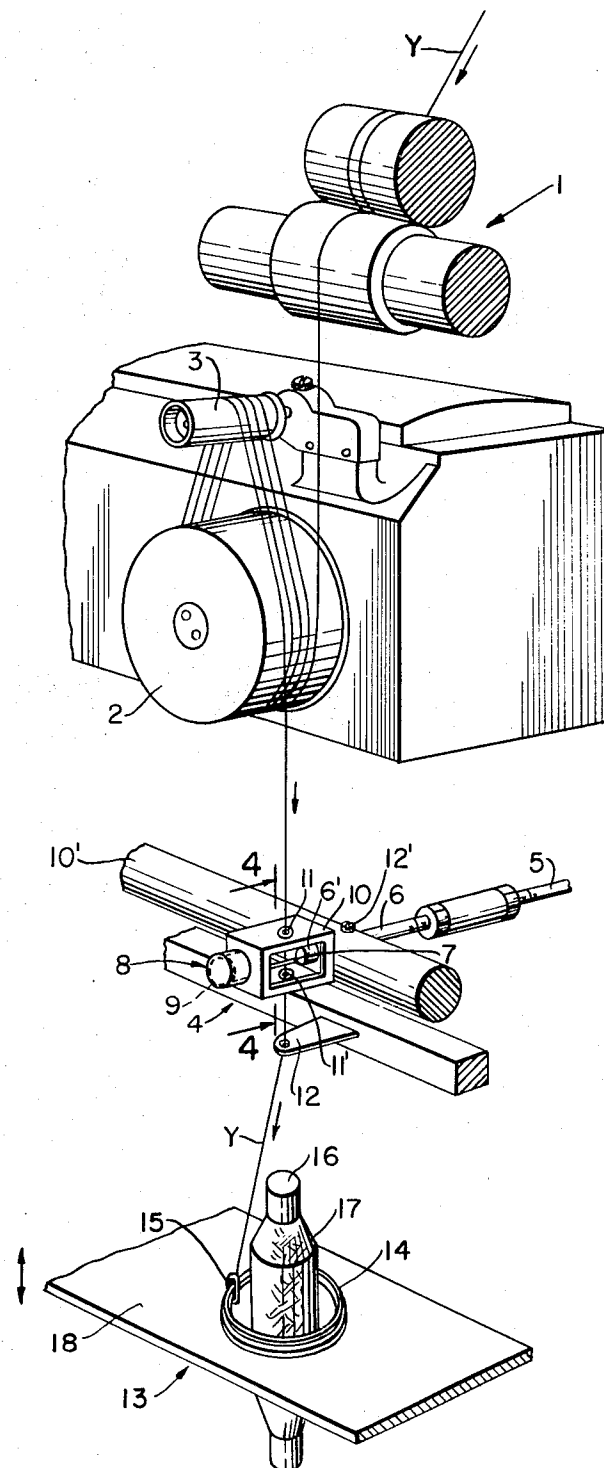
R. F. WHITLEY

3,568,426

UNIFORMLY ENTANGLED MULTIFILAMENT YARN

Original Filed March 27, 1968

2 Sheets-Sheet 1



INVENTOR
ROBERT F. WHITLEY

BY

Roy H. Messingill
ATTORNEY

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2 Sheets-Sheet 2

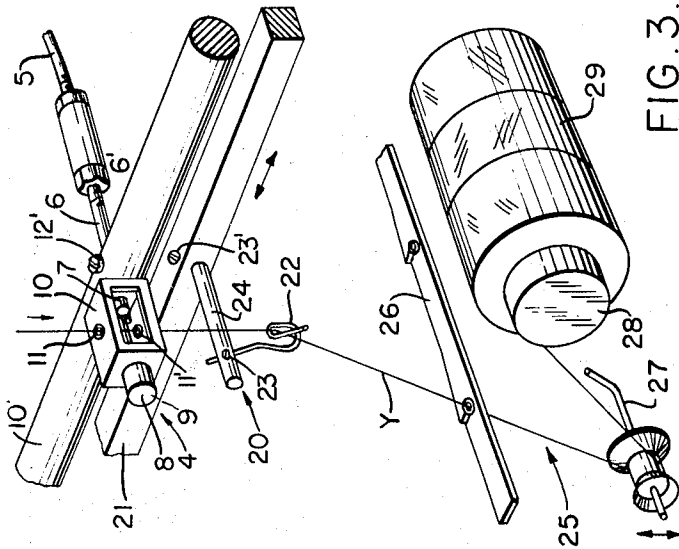


FIG. 3.

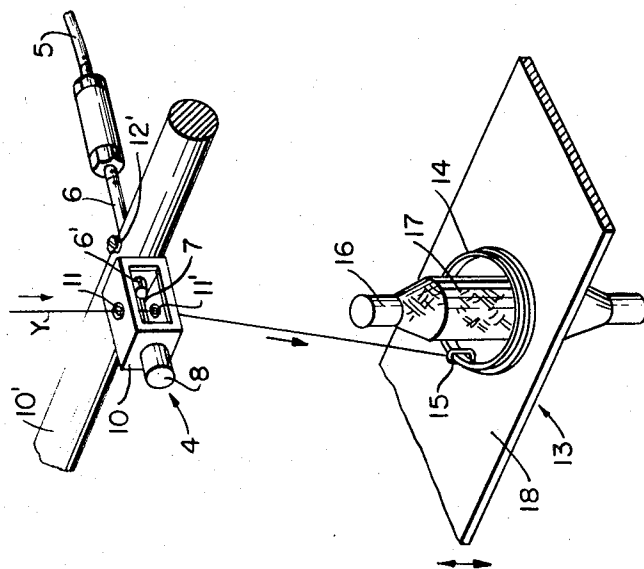


FIG. 2.

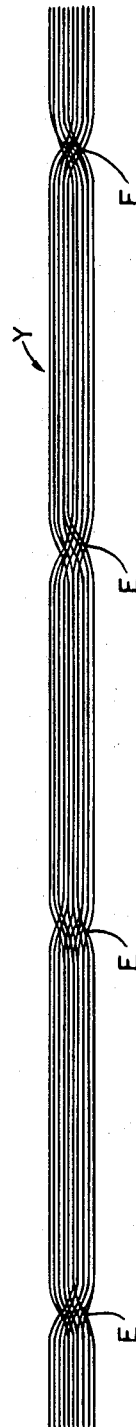


FIG. 5A.

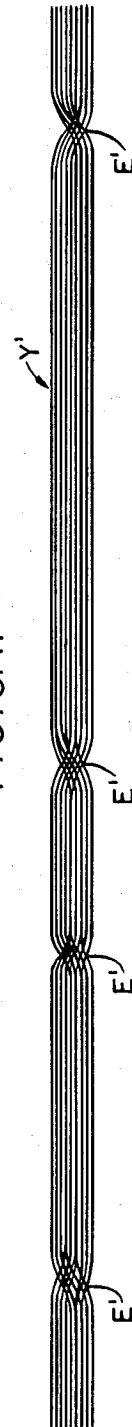


FIG. 5B.

INVENTOR
ROBERT F. WHITLEY

BY

R. H. Messingill
ATTORNEY

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3,568,426

UNIFORMLY ENTANGLED MULTIFILAMENT YARN

Robert F. Whitley, Chester, Va., assignor to Allied Chemical Corporation, New York, N.Y.

Original application Mar. 27, 1968, Ser. No. 716,477, now Patent No. 3,455,096, dated July 15, 1969. Divided and this application Jan. 27, 1969, Ser. No. 822,764

Int. Cl. D02g 1/16, 3/22

U.S. Cl. 57—140

3 Claims

ABSTRACT OF THE DISCLOSURE

Multifilament yarn is produced containing a series of uniformly spaced regions of entanglement, each of said regions involving a majority of the filaments constituting the yarn, as well as being of generally constant length and having a low variability in the degree of entanglement. The production of such yarn can be coupled directly with other yarn treating operations, e.g., drawtwisting, without impairment of yarn quality due to variations in the tension of the running yarn. Yarns so produced have improved dyeing qualities.

This is a division of application Ser. No. 716,477 filed Mar. 27, 1968, now U.S. Pat. No. 3,455,096.

This invention relates to entangled multifilament yarn. More particularly, it relates to an improved product and process of subjecting a running multifilament yarn to the action of a fluid jet which strikes the yarn to produce vibration of the yarn filaments back and forth along the jet axis. Vibration is generally confined to the yarn segment passing between a pair of guides, one of which is upstream from the fluid jet and the other downstream in the direction of yarn travel. Thereby the filaments entangle and intertwine randomly, without noticeable bundle twist, as can be observed by focusing a microscope upon various filaments and following each through the path it takes within the yarn bundle. This random entangling and intertwining action is distinguished from the action of fluid jets in which fluid rotation is developed and the filament bundle is caused to undergo "false twist."

Multifilament yarn wherein the filaments are randomly intertwined, or entangled along the entire length of the yarn, or, more commonly, in discrete regions along the yarn axis, is known to be superior under certain conditions to multifilament yarn wherein the filaments are parallel throughout the length of the yarn. In particular, multifilament yarn containing regions along the yarn axis wherein a majority of the filaments are entangled has better weaving and knitting qualities than exclusively parallel filament-yarn, presumably due to the greater coherency within the entangled yarn.

Fluid jet entangling operations, conducted in accordance with the prior art, are disclosed, for example, in Courtaulds' Canadian Patent 554,150 issued Mar. 11, 1958 to Hartley. When, as in the present invention, it is desired to subject a filament bundle to back-and-forth vibratory action in a jet, it is important to center the yarn bundle accurately upon the jet axis to avoid the aforementioned bundle rotation and twisting effects. Conventionally, such centering has been achieved by restraining the filament narrowly in guides upstream and downstream from the jet. Such guides can take the form of eyelets of diameter not greater than the diameter of the orifice from which the jet issues. Alternatively, they can take the form of V-slots with means to confine the running yarn at the closed end of each slot.

It has been proposed that multifilament yarn may be entangled using a fluid jet apparatus of the type described

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above in conjunction with various yarn treating operations, such as drawtwisting, draw-winding, and the like. However, the results obtained by coupling such yarn treatment, particularly drawtwisting, directly to a yarn entangling device have not been satisfactory. Thus when yarn entanglement is combined with drawtwisting, the traversing action of the twister ring rail up and down the yarn package shortens and lengthens the yarn path to the traveller and sets up varying tensions of the order of 0.1 to 0.15 g./denier in the yarn passing thereto. Since the degree of entanglement, as measured, for example, by the so-called "hook-drop test," varies with varying over-feed or varying tensions the yarn obtained when the entangling operation is coupled directly with drawtwisting shows wide variation within a given yarn sample in the individual values of the hook-drop test. Even the averages of series of 25 hook-drop tests per sample, made on yarns produced at different twisting positions and each presumably identical, vary widely. Thus, when a 70-denier, 32-filament yarn was entangled and forwarded directly to a drawtwister according to conventional methods, a product was obtained which exhibited hook-drop test averages for 5 positions varying from 0.7 cm. at one position to 5 cm. at another position. Such variability is greater, the greater the number of filaments in the yarn. In nylon yarn having 16 or more filaments, such variability is found to adversely affect the uniformity of dyeing of fabric made from such yarn. The more highly entangled yarn segments tend to produce so-called "dye flashes" in the fabric, possibly because the length of the entangled segment is unduly long. Consequently, when a degree of entanglement is sought averaging about 15-40 entanglements per meter (hereinafter referred to as e.p.m.)—i.e. hook-drop averages of between about 6 cm. and about 2.5 cm.—the direct coupling of a yarn twisting operation with the entangling operation is found to result in at least 15% of the individual hook-drop replications (carried out on several samples) showing values of 2 centimeters and below.

Accordingly, it is an object of the present invention to provide a multifilament yarn containing a series of uniformly-spaced regions of entanglement.

Another object is to provide a multifilament yarn containing a series of uniformly-spaced regions of entanglement, each region of entanglement being of generally constant length and exhibiting a low variability in the degree of entanglement.

Another object is to provide a multifilament yarn containing a series of uniformly-spaced regions of entanglement, each of said regions having a degree of entanglement which involves at least a majority of the filaments.

Another object is to provide a process for producing an entangled multifilament yarn having the characteristics of the yarn in the aforementioned objects.

Another object is to provide a process for producing an entangled multifilament yarn having the characteristics of the yarn in the aforementioned objects coupled with yarn treatment such as drawtwisting.

Another object is to provide an apparatus for producing an entangled multifilament yarn having the characteristics of the yarn in the aforementioned objects.

Yet another object of the present invention is to provide an apparatus comprising means for producing an entangled multifilament yarn having the characteristics of the yarn in the aforementioned objects coupled with yarn treatment means such as a drawtwister.

Further objects as well as a fuller understanding of the present invention can be had by reference to the following detailed description and claims.

According to the present invention, a running multifilament yarn composed of at least about 16 filaments is rapidly traversed from side to side, across and out of the

axis of a jet of fluid, preferably a gaseous fluid, e.g., air, nitrogen, and the like. The fluid jet is directed to strike the running yarn, preferably at a right angle to the yarn axis, whereby the intensity of yarn vibration due to the action of the fluid jet stream alternately increases and diminishes. As a result, the yarn is entangled in short, stable, and compactly entangled (i.e., intertwined) segments uniformly spaced along the length of the yarn between segments of essentially parallel filament yarn. Each of the entangled segments is formed by the mutual entanglement or intertwining at random of at least a major proportion or majority of the individual filaments composing the yarn. In the process of the present invention, the traverse frequency (i.e., the rate at which the yarn completes a cycle back and forth across the fluid jet stream in either a circular or linear fashion) is at least about 100 times per second. By adjusting the speed of the running yarn, the traverse frequency, and the scope or distance perpendicular to the fluid jet stream over which the yarn traverses (hereinafter referred to as "traverse amplitude"), it is possible, according to the present invention, to produce a yarn in which the length of the entangled segments can be adjusted to and maintained at an average of not greater than about 0.4 centimeter and preferably not greater than about 0.3 centimeter as measured by passing the entangled yarn with 2% stretch around a pin and measuring the lengths of those segments which resist flattening and retain, while passing over the pin, at least 33–50% of the thickness of the yarn when under no tension. The average spacing of these entangled segments in yarns processed in accordance with the present invention, lies between about 2.5 centimeters and about 6 centimeters. Using the "hook-drop" method of testing, it is found that no more than about 10% of the spacings between entangled segments are ever less than about 2 centimeters long.

By virtue of the above features of the present invention, it is possible to successfully couple the yarn entangling step with other yarn treatment operations which tend to cause variations in yarn tension which in turn cause variations in the quality and uniformity of the entangled yarns of the prior art. It is especially desirable to couple the yarn entangling step with a twisting or drawtwisting operation. In those instances when the yarn product is uniformly twisted or drawtwisted it is preferable that the degree of twist lie somewhere between about 0.2 and about 3 turns per inch (hereinafter referred to as t.p.i.). By virtue of the aforementioned properties, the yarn product of the present invention, whether drawtwisted or not, has dyeing characteristics superior to those of analogous prior art yarns. More specifically, entangled multifilament yarns of the present invention are not susceptible to dye flashes.

A further understanding of the present invention can be had by reference to the accompanying drawings wherein:

FIGS. 1–3 are schematic diagrams illustrating various preferred embodiments of the process and apparatus of the invention;

FIG. 4 is a vertical section of the jet entangling device 4 of FIGS. 1–3 taken through the center line of guides 11, 11' in the direction indicated on line 4–4 of FIG. 1; and

FIGS. 5A and 5B are greatly enlarged and partially diagrammatic views of the entangled yarn products of the present invention and of the prior art, respectively.

Referring to FIG. 1, yarn Y is shown passing between feed rolls 1 to draw roll 2 and around draw roll 2 and separator roll 3 in several wraps. From draw roll 2, yarn Y passes to a fluid jet entangling device generally indicated by 4. Entangling device 4 comprises a source 5 of gaseous fluid under controlled pressure, a conduit 6 which forms the gaseous fluid into a jet stream, a nozzle 6' which is secured to and which forms the terminus of conduit 6, and a jet stream orifice 7 in nozzle 6' which

attenuates the fluid jet stream and directs it, with negligible divergence, toward resonance chamber 8 having a cavity 9 therein. The mouth of cavity 9 faces jet stream orifice 7. Resonance chamber 8 is secured to frame 10 which in turn is secured to nozzle 6'. Entangling device 4 is secured as a unit to stationary rail 10' by means of set screw 12' which operates to secure rail 10' to conduit 6. Within rigid frame 10 are located upstream and downstream guides 11, 11' which lead yarn Y past jet stream orifice 7. From the downstream guide 11', yarn Y passes to conventional balloon guide 12 of a conventional twisting and packaging device 13, comprising ring 14, traveller 15, spindle 16, yarn package 17, and ring rail 18. By means of the vertical traversing action of ring rail 18, the ring and traveller are caused to oscillate up and down yarn package 17 to lay the yarn from top to bottom thereof.

Referring to FIG. 4, the diameter of orifice 7 through which the fluid jet stream issues is less than the diameter of the guides 11, 11'. Guides 11, 11' are preferably made of wear-resistant material, e.g., ceramic, and are desirably in the form of inserts positioned in rigid frame 10 so that their line of centers bisects the line segment lying between the center of orifice 7 and the center of the mouth of cavity 9.

Referring to FIG. 2, there is depicted a process and apparatus like that of FIG. 1 which differs in omitting the conventional balloon guide (12 of FIG. 1) normally used with twist winders. The remaining elements shown in FIG. 2 are the same as in FIG. 1 and bear the same reference numerals.

Referring to FIG. 3, there is depicted another preferred alternative form of the process and apparatus of the present invention. The elements which are the same as those of FIG. 1 are indicated by the same reference numerals as employed in FIG. 1. The apparatus shown in FIG. 3 utilizes, instead of the fixed balloon guide 12 of FIG. 1, a yarn guide assembly generally indicated by 20. Yarn guide assembly 20 comprises a "pigtail" yarn guide 22, whose shank is slidably mounted within supporting arm 24 and secured thereto by means of set screw 23. Supporting arm 24 is likewise slidably mounted within supporting beam 21 and secured thereto by means of set screw 23'. Guide assembly 20 rapidly oscillates directly below guide 11' in the direction generally perpendicular to the direction of the fluid jet stream and perpendicular to the line of centers of guides 11, 11'. This oscillation is imparted to guide 20 as supporting beam 21 rapidly reciprocates lengthwise in a direction generally parallel to stationary rail 10'. Supporting beam 21 and rail 10' are maintained parallel to each other by conventional means, e.g., by means of a bushing arrangement (not shown) slidably mounted on stationary rail 10' and secured to supporting beam 21. From the foregoing description of FIG. 3, it is seen that the yarn-engaging loop of pigtail guide 22 can be adjusted to a desired position relative to downstream guide 11' by suitable adjustment of set screws 23, and 23'. From yarn guide assembly 20, yarn Y passes to a conventional take-up apparatus 25 for taking-up the entangled yarn without twist. Take-up apparatus 25 comprises traverse guide 26, a tension regulating arm 27, and roll 28 upon which parallel-wound yarn package 29 is collected.

In the operation of each of the processes and apparatus of FIGS. 1–3, an undrawn yarn Y is passed from the feed rolls to the draw rolls and thence is passed to upstream guide 11 of jet entangling device 4. The jet entangling device is aligned so that a plumb line tangent to draw roll 2 passes through the centers of guides 11 and 11' and through balloon guide 12 of FIG. 1 through the yarn-engaging loop of pigtail guide 22 of FIG. 3. Such plumb line also passes through the center of spindle 16 of FIGS. 1 and 2.

When traveller 15 of the twisting and packaging device 13 of FIGS. 1 and 2 circles around ring 14, the yarn Y is

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carried in a circular path around the peripheries of guides 11, 11'. Since the center line of the guides passes directly through the axis of jet stream orifice 6, this circular motion of the yarn causes the yarn to traverse from side to side across and out of the axis of the fluid jet stream, twice for each complete revolution of the yarn around the peripheries of the guide.

In the operations of FIG. 3, the yarn is caused to traverse from side to side within the guides 11, 11' and across and out of the axis of the fluid jet stream by the reciprocating motion imparted to the yarn by oscillating yarn guide assembly 20. The loop of pigtail guide 22 is adjusted to a position directly below guide 11', on the center line through guides 11, 11'. The amplitude of the oscillation of guide assembly 20 is restricted to that sufficient to traverse the yarn from one side of the guides 11, 11' to the other and across and out of the axis of the fluid jet stream. Too wide an oscillation could set up unnecessary variations in the yarn tension. It is frequently desirable, when using an oscillating yarn guide such as guide assembly 20, to position such guide so that it snubs the yarn beyond the jet entangling device. Thereby the tension variation occasioned by windup of the yarn can be largely confined to the yarn segment downstream from such oscillating guide, with resulting improvement in uniformity of the entangled yarn produced. Such a snubbing action is shown in FIG. 3.

Referring to FIG. 5A there is diagrammatically illustrated the improved, uniform yarn product of the present invention, Y, having uniformly spaced, highly entangled segments E of relatively short and constant length. The improved product of this invention can be essentially a zero twist yarn as produced in accordance with FIG. 3, or can be a twisted yarn as produced in accordance with FIGS. 1 and 2. By way of comparison, the randomly entangled yarn Y' produced in accordance with the prior art is diagrammatically illustrated in FIG. 5B, showing the irregular length and varying degrees of entanglement characteristic of the entangled segments E' of such prior art yarn.

It is understood that the process of the present invention is applicable to the entanglement of multifilament yarn which can be either drawn (as shown in the drawings) or undrawn, and which can comprise filaments of one color or a plurality of colors. The present invention can also be applied to multifilament yarns in which the individual filaments differ in denier and chemical composition.

The fluid jet stream used to produce the entangled yarn of this invention can be a liquid or a gas, at any desired temperature. Preferably a gas is used, particularly air at ambient temperature.

In accordance with the present invention, the guides through which the yarn is forwarded into and out of the zone of jet action can be of any curvilinear shape, preferably circular, and are specially constructed to promote smooth yarn traversing from side to side as the yarn is passing through the jet stream. One or both of these guides can itself be caused to traverse rapidly from side to side to carry the yarn across and out of the axis of the fluid jet stream. Alternatively, these guides can be stationary but large enough to allow a traversing motion of the yarn, imparted by means outside the guides, to be transmitted to the yarn as it passes through the jet stream. In particular, the guides can be stationary and have a crosswise dimension of preferably between about 1.5 fold and about 5 fold the crosswise dimension of the orifice from which the fluid jet stream issues (assuming negligible divergence of the fluid jet stream between the orifice and the yarn). The yarn can have a circular motion about the peripheries of the guides or a linear motion from one side of the guides to the other side, in a rapid traversing motion across the fluid jet stream.

Stroboscopic observation of the yarn using high speed motion picture photography shows that as a result of such

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traversing motion, the intensity of yarn vibration increases to a maximum and then greatly diminishes as the yarn bundle traverses from one side of the guides to a central position in front of the jet stream orifice and then crosses the axis of the fluid jet stream and passes out of the zone thereof when approaching the other side of the yarn guides.

The apparatus above specified is particularly suitable for coupling with a conventional ring and traveller twisting device. When the traversing action is produced by such a ring and traveller device, the uniformity of the degree of entanglement improves as the fluid pressure at the jet stream orifice increases from about 30 p.s.i.g. up to about 60 p.s.i.g. Further pressure increases do not significantly increase the degree of entanglement. Furthermore, at pressures less than 60 p.s.i.g., the entanglement will not reach such high levels as to cause dye flashes in fabric woven from the yarn provided the yarn is free to traverse in the above-described manner to a position out of the jet axis where the back-and-forth vibration of the yarn due to the action of the jet stream substantially diminishes in intensity.

The degree of entanglement obtained in accordance with this invention is higher, the smaller the distance which the yarn traverses. As above noted the traverse amplitude of the yarn should be at least about 1.5 times greater than the crosswise dimension of the jet stream orifice, in order to maintain the desired restriction upon the length of the entangled yarn segments. During that portion of each traversing cycle when the yarn is outside zone of the jet stream, the entangling action is terminated and the entangled segments stops growing. Correspondingly, the degree of entanglement will be lower, the greater the traverse amplitude under otherwise constant conditions.

The length of the entangled segments and the length of the parallel segments of yarn will be greater, the faster the yarn is forwarded through the zone of the jet stream under otherwise constant conditions. On the other hand, the length and degree of entanglement of the entangled segments and the length of the parallel segments of yarn will be less, the greater the traverse frequency of said yarn under otherwise constant conditions. Accordingly, the length and degree of entanglement of the entangled segments of the yarn can be controlled by suitable adjustment of the yarn windup speed, traverse frequency and traverse amplitude. Multifilament yarn entanglement according to the process and apparatus of the present invention affords excellent uniformity in the length of the entangled segments together with a high degree of entanglement within each entangled segment. The entanglement in each segment will preferably involve at least a majority (i.e., 50% or more) of the filaments constituting the yarn, as indicated by passing the yarn with 2% stretch around a pin which causes the parallel filament segments to flatten out into a ribbon which is essentially only the thickness of a single yarn filament. The entangled yarn segments resist flattening under this test. Wherever these entangled segments are found to retain at least 33% of the original thickness of the yarn, they are adjudged to involve in such region at least a major proportion of the filaments constituting the yarn. The entangled segments are stable in the sense that they remain entangled during normal yarn handling operations such as forwarding, winding, twisting, etc.; they are compact in the sense that they are free of loops, whorls, and the like; and they impart coherency to the multifilament yarn product whereby such yarn is runnable at low twist of 0-3 t.p.i. in operations such as slashing a warp yarn, weaving a warp and filling yarn, tricot knitting, and any type of circular knitting. The process can also be used to combine different types of yarns, e.g., white and colored yarns, and yarns of different dyeing characteristics. Moreover, the structural uniformity of the entangled yarn of the present invention made possible by the short-

ness of each entangled segment and high degree of entanglement in each, confers uniform dyeability upon fabrics made from the yarn of this invention.

The following examples are presented for the purpose of illustrating the present invention without imposing any limitations on the scope thereof.

In the examples, five fluid jet entangling units are aligned vertically on a draw twister so that a plumb-line tangent to the draw roll passes through the center of each of the yarn guides (eyelets) affixed one upstream in the line of yarn travel and one downstream from each jet. While the yarn was running and being twisted, the yarn continually swept around the periphery of the guides, whereby an entangled segment of yarn was produced each time that the yarn was carried across the axis of the jet and in front of the resonance chamber. From the results

and are separated by a center-to-center distance of 20 mm. In Example 1, the guides are 0.120 inch (about 3 mm.) in diameter; in Example 2, the guides are 0.160 inch (about 4 mm.) in diameter; in Example 3, the guides are 0.225 inch (about 5.7 mm.) in diameter.

In the examples, the lengths (in centimeters) of the segments of entangled yarn and parallel filament yarn are measured by the "hook-drop" test described in Du Pont's U.S. Pat. 2,985,995 issued May 30, 1961 to Bunting et al. In the tables of Examples 1-3, the upper figure of each entry is for yarn taken from the upper end of the pirn; lower is for yarn from the lower end. Times of doffing the pirn for sampling appear at the head of each column of data, below the pressure of the air supplied to the jet. A full pirn requires about 4.2 hours to complete. Each row contains data for one of the 5 positions.

EXAMPLE 1.—0.120 INCH (3 MM.) GUIDES

Position	Air pressure							
	80 p.s.i.g.			70 p.s.i.g.			60 p.s.i.g.	
	15 min.	2 hr.	4 hr.	15 min.	2 hr.	4 hr.	15 min.	4 hr.
1-----	2.0	2.5	2.3	4.4	3.8	2.7	4.4	6.0
	2.2	3.7	2.1	4.6	3.7	3.6	6.5	3.9
2-----	2.6	3.1	3.4	3.0	6.0	3.2	4.5	5.5
	3.1	2.1	3.8	5.2	3.1	5.8	6.0	4.5
3-----	2.3	2.0	4.2	3.4	5.1	4.8	4.8	4.8
	2.5	2.6	3.7	4.4	3.6	4.8	6.0	4.2
4-----	2.4	2.5	2.3	3.0	5.1	3.4	4.8	4.4
	5.2	3.0	2.5	4.6	4.3	6.5	8.0	5.2
5-----	2.9	2.5	-----	2.8	4.3	2.9	3.7	3.9
	2.4	2.6	-----	3.4	1.8	3.0	4.6	4.1
Avg. ¹ cm.	2.4	2.6	3.1	3.3	4.4	3.4	4.4	4.9
	3.1	2.8	2.4	4.4	3.3	4.7	6.2	4.4
Avg. ¹ e.p.m.	36.4	37.0	36.4	26.0	24.4	24.7	18.9	21.5

¹ Average.

EXAMPLE 2.—0.160 INCH (4 MM.) DIAMETER GUIDES

Position	Air pressure								
	80 p.s.i.g.			70 p.s.i.g.			60 p.s.i.g.		
	15 min.	2 hr.	4 hr.	15 min.	2 hr.	4 hr.	15 min.	2 hr.	4 hr.
1-----	2.69	2.57	3.83	3.67	4.67	3.93	4.79	4.40	3.37
	3.31	2.64	3.43	5.13	4.14	3.73	6.15	6.00	4.23
2-----	3.78	4.68	3.31	3.99	3.63	3.69	4.41	4.94	4.64
	5.97	2.59	2.65	4.89	3.19	4.25	5.64	4.15	4.96
3-----	2.70	4.33	3.42	2.90	4.85	3.97	5.47	4.45	5.80
	2.51	4.73	3.28	4.76	5.04	3.83	5.09	3.94	4.48
4-----	4.33	2.96	4.20	4.39	4.18	3.12	4.12	5.51	3.07
	5.16	3.68	4.55	4.29	5.04	3.31	6.35	5.49	4.47
5-----	2.57	4.43	3.52	3.71	3.77	3.93	4.08	3.69	5.31
	5.67	3.40	2.97	5.61	3.19	4.07	7.32	3.52	4.09
Avg. ¹ cm.	3.20	3.80	3.64	3.74	4.20	3.72	4.58	4.60	5.30
	4.51	4.60	2.93	4.14	4.10	3.94	6.10	4.60	4.48
Avg. ¹ e.p.m.	25.8	25.6	30.7	25.3	24.1	26.1	18.7	21.7	20.4
Total e.p.m.		27.1			25.2		20.2		

¹ Average.

tabulated below, it is evident that tension variations have little or no effect on the degree of entanglement obtained.

Five positions on the drawtwister are used (each as described above in connection with FIG. 3).

In each example, the feed yarn is 70-denier drawing yarn composed of 32 filaments of semidull nylon-6. The windup speed is 800 meters/min. at a spindle speed of 8600 r.p.m. The drawtwister is operated to impart a uniform twist to the yarn of 0.27 t.p.i.

The resonance chamber is essentially the same as that shown in the drawings, having the dimensions of a cylindrical cavity 2.5 mm. deep and 3.5 mm. inside diameter. The mouth of the resonance chamber has the form of a truncated cone, converging at 45° taper from 9.6 mm. diameter to 3.5 mm. diameter.

The fluid jet stream orifice has a diameter of 1.5 mm. and is backed by a collimating passage within the jet nozzle of length 9.5 mm. The distance between the jet stream orifice and the mouth of the resonance chamber is 10 mm.

The fluid jet stream comprises air at ambient temperature.

The yarn guides of each entangling unit are circular

EXAMPLE 3.—0.225 INCH (5.7 MM.) GUIDES (6 POSITIONS USED)

Position	Air pressure			
	80 p.s.i.g.		60 p.s.i.g.	
	15 min.	2 hr.	15 min.	2 hr.
1-----	5.55	4.35	5.0	7.43
	4.48	4.91	7.0	5.75
2-----	7.06	6.09	2.8	7.32
	7.0	4.47	6.1	5.97
3-----	6.23	6.05	7.9	8.45
	6.2	3.65	5.1	5.61
4-----	7.77	6.41	5.8	6.23
	6.29	4.47	9.4	5.25
5-----	7.91	6.87	10.8	8.17
	6.05	4.17	8.5	6.15
6-----	5.92	5.95	7.5	6.93
	6.24	4.33	7.8	6.45
Average e.p.m.	16.2	19.8	14.3	15.2

The yarn produced at each position in the above Example 2, as will be noted, given average results in the hook drop test which, for the great majority of the entries in the table, range from 6 cm. down to 2.5 cm.; for the individual replications, at least 90% of the results have values of at least 2 cm. All entries obtained at 70

p.s.i.g. and at 80 p.s.i.g. in the table of Example 2 are in the 6 cm. to 2.5 cm. range.

Moreover when tested by passing at under 2% stretch over a pin to flatten out the non-entangled yarn segments into a ribbon, the yarns of Example 2 show segments which resist flattening and retain at least 33-50% of the original thickness of the yarn as measured under zero tension, i.e., they retain thicknesses of at least about 1.2 mils (for untwisted yarn) to 1.8 mils (for twisted yarn) for 70-denier, 32 filament-count yarn having a thickness per filament of about 0.6 mil. In the tests of Example 2, these segments number about 15 to 40 per meter of yarn length on the average, which number represents a measure of yarn entanglements per meter. This method of measuring yarn entanglements per meter checks satisfactorily with the hook drop test as can be seen from the figures for "avg. e.p.m." reported in Example 2 and calculated by dividing 100 by the average hook-drop distances in centimeters as given in Example 2. The test just described, wherein thick segments of yarn passing over a pin are detected, can be used as a method of measurement of the length of the entangled segments and the length of the entangled segments and the length of the segments of essentially parallel filament yarn. Such a test confirms the visual observation that in the yarn of Example 2, the entangled segments generally involve at least the major proportion (i.e., 50%) of the individual filaments composing the yarn, and these segments do not average above $\frac{1}{8}$ " in length. Further, these measurements confirm the hook-drop results in showing that, in the yarn of Example 2, the spacing of the entanglements is regular in the sense that the intervening segments of essentially parallel filament yarn are of relatively uniform length such that at least 90% of these parallel yarn segments are at least 2 centimeters in length. The entanglements in the yarn of Example 2 show no evidence of bundle twist along an entangled segment, or other regularity of filament intertwining, except for the uniform twist imposed along the whole yarn length by the action of the ring and traveller twisting and packaging apparatus.

Of course there will be equivalent means of carrying out the invention, differing in form from those specifically described above, as one skilled in the art of designing processes and apparatus for yarn treatment will recognize. For example, the required traversing of the yarn across and out of the axis of the jet stream can be accomplished (where the jet stream is along a horizontal axis) by maintaining the running yarn substantially in one vertical plane while causing the jet stream axis to traverse in and out of the said vertical plane. For instance, by self-actuated revolution of the jet nozzle in a

circle the axis of the jet stream will be caused to describe a cone, and will thereby accomplish the required relative traversing of the jet stream axis by the yarn, by causing the jet stream axis to rapidly traverse the yarn axis. A further example of the many variants within the scope of the present invention is to achieve the intermittent entanglement of the multifilament yarn by adapting the fluid jet stream delivery means to be rapidly turned on and off, thereby delivering an intermittent flow of filament-entangling fluid to the yarn. Yet another variant of the present invention involves the use of a relatively high spindle speed and/or low drawing speed in conjunction with a given eyelet diameter. An entangled yarn is thereby produced having a single, continuous entanglement throughout the entire length of the yarn.

I claim:

1. An improved entangled multifilament yarn comprised of at least about 16 filaments having between about 15 and about 40 entanglements per meter of yarn in the form of short, compact, stably coherent entangled segments spaced at uniform intervals along the yarn length, said entangled segments being formed by the mutual entanglement at random of at least the major proportion of the individual filaments of the yarn, said segments having an average length less than about 0.4 centimeter and being spaced between about 2.5 and 6.0 centimeters apart, said filaments between said segments being essentially parallel.

2. An improved entangled yarn as described in claim 1 wherein at least 90% of the entangled segments are spaced at least about 2.0 centimeters apart as measured by the hook-drop test.

3. An improved entangled yarn as described in claim 2 wherein the entangled segments retain at least about 33 percent of the original thickness of the yarn under no tension, while passing said yarn around a pin under about 2 percent stretch.

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JOHN PETRAKES, Primary Examiner

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