March 5, 1957 A. L. BREEN 2,783,609

BULKY CONTINUOUS FILAMENT YARN

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Fig. 1.

Fig. 8.

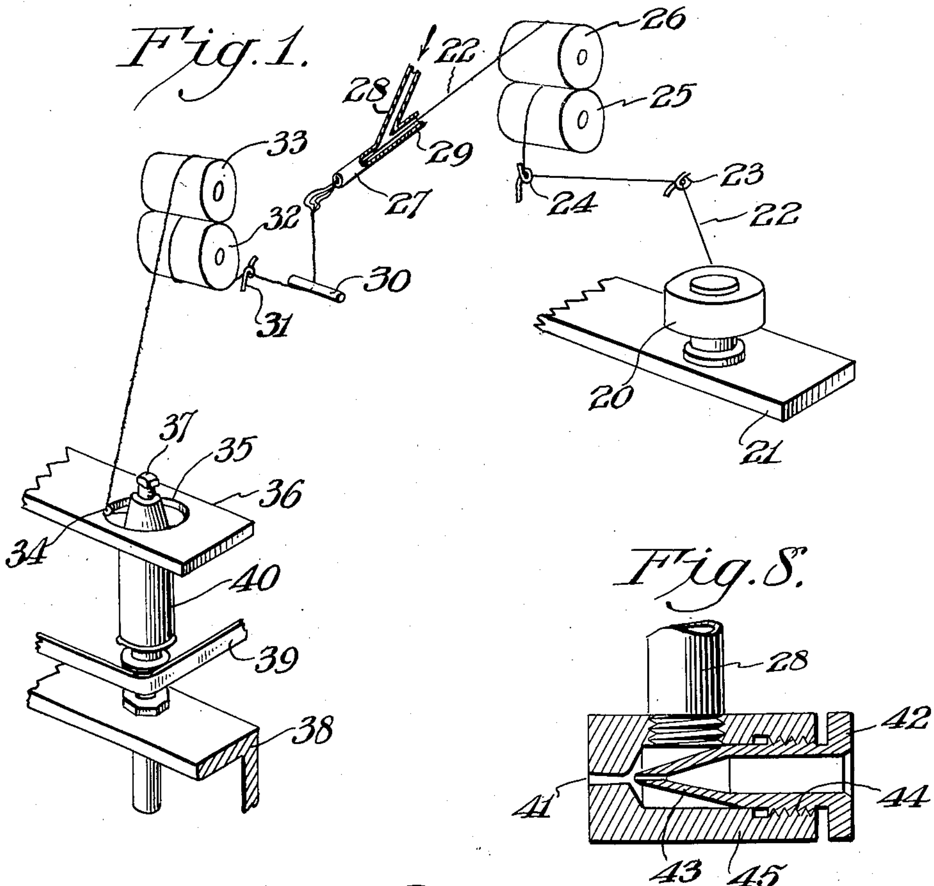

Fig. 9.

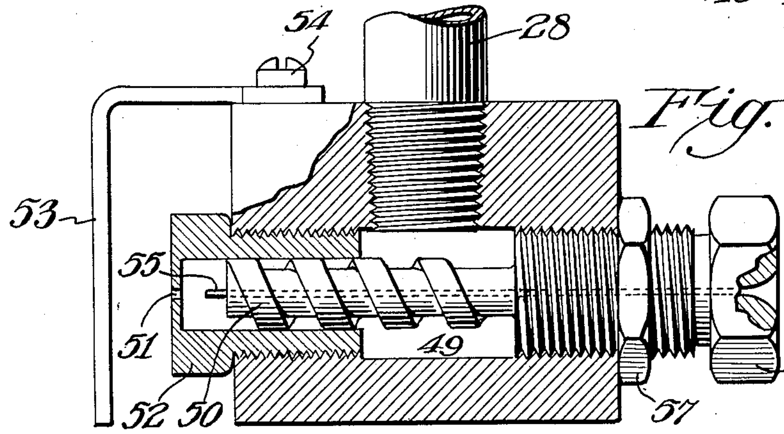

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Fig. 2.

Fig. 3.

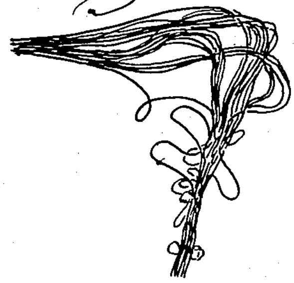


Fig. 4.

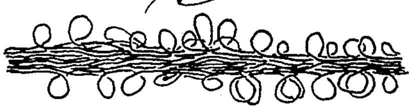
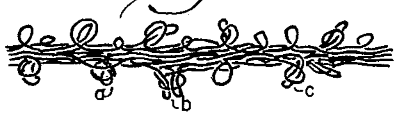


Fig. 5.

Fig. 10.

Fig. 7.



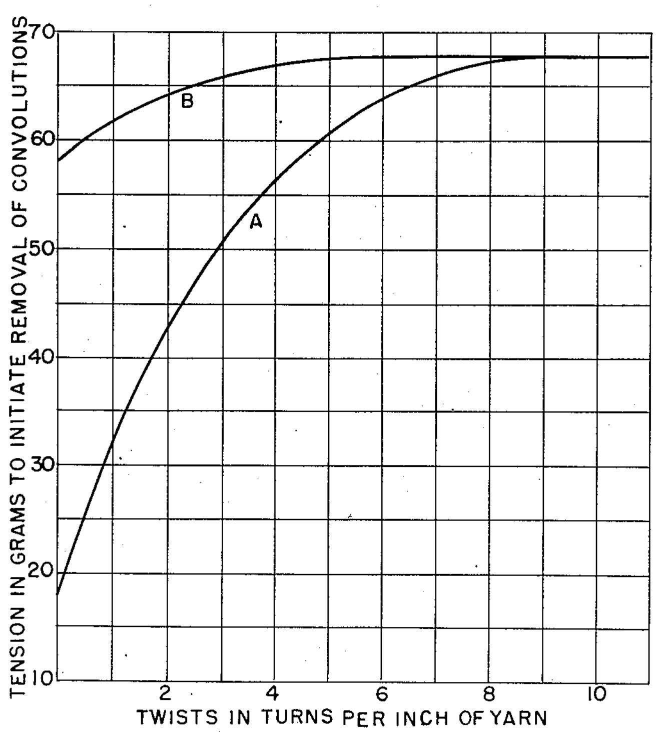


Fig. 6.

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BULKY CONTINUOUS FILAMENT YARN

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Application December 14, 1951, Serial No. 261,635

15 Claims. (Cl. 57—140)

This invention relates to process and apparatus for treating a bundle of continuous filaments, such as a yarn or thread, to produce a multifilament yarn of greatly increased bulk, and to the novel bulky yarn produced. More particularly, the invention relates to a bulky yarn composed of a plurality of individually convoluted filaments, and to the process and apparatus used for preparing such yarn.

With the outstanding exception of silk, all natural animal, vegetable and mineral fibers exist in only relatively short lengths. The production of yarn from such staple fiber is a time-consuming operation which usually requires a complex series of operations to align the fibers, combine them into an elongated bundle, and draw the bundle to smaller diameter while twisting to prevent excessive slipping of adjacent fibers past each other. Further spinning operations finally produce yarn or thread useful in textile operations.

All, or nearly all, artificial fibers are produced most easily as continuous filaments. Formation of continuous filaments into yarn is much simpler than staple processing. Continuous filament yarns may be made very strong because of the absence of loose ends that are unable to transmit imposed stresses. However, because of their extreme uniformity and lack of discontinuities, conventional continuous filament yarns are much denser than their staple counterparts. The filaments lie close together in the yarn, and adjacent strands of continuous filament yarn in fabrics are closely spaced. This compactness limits the amount of insulating air space present. The lack of occluded air space greatly restricts the usefulness of such continuous filament fabrics. Lightness, covering effectiveness, and warmth-giving bulk are essential for many uses. Hence a large amount of the total continuous filament production of such fibers as viscose rayon, cellulose acetate, nylon and polyacrylonitrile has been cut into short lengths for spinning into staple yarn.

Previous efforts to produce continuous filament yarn having the desirable qualities of staple yarn have been unsuccessful. These efforts have been concerned primarily with modifying the internal structure of the filaments, as by physical or chemical distortion. Mechanical crimping or twisting of filaments has produced undulating or spiralled fibers, but the effect has been disappointing. Similar unsatisfactory results have been obtained by imparting motion to the spinning head and by chemical treatment of the spun filaments. All known methods have been unsatisfactory for one reason or another, such as insufficient bulkiness, unsatisfactory distribution of stress-bearing portions of the filaments, undesirable modification of fiber properties, impermanence of form, or complexity and expense of the operations.

It is an object of the present invention to provide continuous filament yarn having a bulkiness at least as great as that of staple yarn spun from comparable fibers and having the same average number of filaments per cross-section. Another object is to provide multifilament yarn resembling spun staple in its desirable lightness, covering effectiveness and warmth-giving bulk but retaining the characteristic continuous filament freedom from loose ends, fuzziness and pilling. Another object is to provide bulky multifilament yarns of finer deniers than can be spun practicably from staple. A further object is to provide a process for preparing continuous filament yarn having a bulk equal or superior to that of comparable staple yarn without abrading or cutting the constituent filaments and without deforming or otherwise modifying their structure. A still further objec tis to provide such a process which is suitable for rapidly and economically treating ordinary multifilament continuous yarn to greatly increase the bulk without the use of moving mechanical parts other than in the windup. Yet another object is to provide suitable apparatus for practicing the above process. Other objects of the invention will become apparent from the following description and claims.

In this invention, a yarn fulfilling the above objectives has been produced, composed of a plurality of substantially continuous, individually convoluted filaments. The individual filaments have coils, loops or whorls at random intervals along their lengths. Unless otherwise indicated the term "loops" in the present specification refers to tiny complete loops formed by a filament doubling back upon itself, crossing itself and then proceeding in substantially the original direction. In mathematics a curve of this type is said to have a crunode. Accordingly the term "crunodal loops" will be used when it is necessary to distinguish the loops characteristic of this invention from other forms of loops. The majority of loops visible on the surface of the yarn are of a roughly circular or ring-like shape. The crunodal loops inside of the yarn are not readily studied, but it is evident that pressure of surrounding filaments will tend to cause such loops to assume more complex shapes. The most obvious characteristics of the novel continuous filament yarn are its bulkiness and the presence of a multitude of filament ring-like loops irregularly spaced along its surface. These readily visible filament loops contribute to bulkiness, but the less obvious convolutions of the filaments within the yarn provide a lateral interfilament spacing which is important in producing the bulk and resulting garment warmth of fabrics made from this yarn.

The convolutions of the filaments may be held in place by the twist usually imparted to yarn. When this is done, the absence of internal structural change may be shown by untwisting the yarn and taking it apart, whereupon the individual filaments will return to substantially their original condition. When ordinary straight filaments are used to prepare the bulky yarn, substantially straight filaments are obtained by unbulking the yarn. Of course, crimped, wavy or curly filaments could be processed according to this invention, and such filaments would resume their respective starting configurations when separated from the yarn. Some reduction of tensile strength below that of ordinary continuous filament yarn may be expected because, at any given point in the bulked yarn of this invention, some of the filaments may not be placed under tension when the yarn is pulled, but this may be minimized or offset by increased twist, production of the loop-within-a-loop configuration described below, or by a treatment, such as steaming, to impart a permanent set.

A similar yarn might be prepared from a bundle of continuous filaments by tedious hand manipulation. An individual filament would be separated and slack formed in the filament. The slack would be taken up by forming a minute coil or loop in the filament and holding it in place by twisting the filament bundle or by encircling this loop by a similar convolution formed in a nearby filament. Repetition of this operation at intervals along each and every filament could eventually give the desired yarn structure.

In accordance with this invention a process has been devised for producing the described yarn structure rapidly with surprising simplicity.

In the preferred process of this invention, a stream of air or other compressible fluid is jetted rapidly from a confined space to form a turbulent region. Yarn to be treated is fed into the fluid stream so that the yarn is supported by it and the individual filaments are separated from each other and whipped about violently in the turbulent region. Merely removing these separated filaments from the turbulent region for reassembly into a yarn accomplishes the desired result of forming loops and other convolutions at random intervals along each filament and irregularly spaced on different filaments. The filaments are whipped about in the turbulent zone sufficiently to form convolutions that are retained during withdrawal, windup and further processing.

The invention will be better understood by reference to the drawings. In these drawings, which illustrate preferred embodiments of the invention,

Figure 1 is a schematic perspective view of suitable equipment for manufacturing bulky continuous filament yarn in accordance with the invention,

Figure 2 is a side view showing the appearance of untreated yarn being fed to the air jet (enlarged about ten times),

Figure 3 is a side view of the yarn leaving the air jet and being pulled downward out of the turbulent zone (enlarged about ten times),

Figure 4 is a side view showing the appearance of treated yarn before twist is applied (enlarged about ten times),

Figure 5 is a side view showing the appearance of bulky yarn after twist has been applied (enlarged about ten times),

Figure 6 is a graph showing how the yield point (initial loop-removal tension, measured as described below) increases with the twist applied to bulky yarn,

Figure 7 is a side view of yarn treated by a modification of the bulking process (enlarged about ten times),

Figure 8 is a modified form of air nozzle for use in practicing the invention,

Figure 9 is another modification of nozzle, and

Figure 10 shows the arrangement of filaments in a cross-sectional slice taken through fabric woven from the bulky continuous filament yarn of this invention (enlarged about 50 times).

Referring to Figure 1, the continuous filament yarn to be treated may be supplied from any suitable source, such as a yarn package **20** supported on a creel **21**. Untwisted yarn will normally be used, but twisted yarn can be used satisfactorily by increasing the filament-separating action, as by using higher pressure. The yarn can also be supplied directly from the spinning process by which it is produced, without any intermediate wind-up. The yarn **22**, from whatever source is selected, passes through guides **23** and **24**, between feed rolls **25** and **26**, and to air nozzle **27**. This nozzle consists of a compressed air pipe **28** screwed or brazed into yarn tube **29**, shown partly in section. The pipe and tube are arranged at an angle so that a flow of air is produced through the tube sufficient to carry the yarn along. The tube **29** can be as little as 1 inch long and 0.05 inch inside diameter.

The appearance of the yarn entering the air jet **27** is shown in Figure 2. The filaments are relatively straight and closely packed, giving the yarn a rod-like appearance. As shown in Figure 3, the yarn leaving the air jet is blown apart by the air stream. High speed motion pictures have shown that the individual filaments are whipped around violently by the turbulent air. As the filaments are withdrawn from the region of turbulence, they are swirled into convolutions which may be held in place by adjacent filaments of the reforming yarn bundle. After passage through the turbulent zone and reforming into a yarn, the appearance of the bundle of filaments may be as shown in Figure 4. These filaments are only loosely grouped and a strong pull would remove the bulkiness if it were not stabilized by additional treatment, preferably by twisting the filaments together.

The loose bundle of filaments is directed by guides **30** and **31** to take-up rolls **32** and **33**, and then passes to a wind-up device such as the down-twister shown. As is usual with this device, the yarn is given a twist as it is wound by passing through a traveller guide **34** sliding around on ring **35** mounted on ring rail **36**. The yarn is collected on spindle **37**, supported by spindle rail **38** and rotated by belt **39**, to form a package of finished yarn **40**. The appearance of twisted yarn produced in this way is shown in Figure 5. In the actual yarn loops may be less than 1 millimeter in size. The loops and other convolutions of individual filaments are firmly held in place by friction between filaments. Increasing the twist increases this friction between filaments and holds the convolutions more firmly in place.

Figure 6 shows the effect of increasing amounts of twist on the yield point of typical yarns. Yield point may be defined roughly as the tension required to initiate removal of the convolutions. It is measured by tensioning the yarn and plotting points on the resulting stress-strain curve. At first, a steep, nearly straight line results, representing the elastic modulus. As slippage occurs, the points generally scatter about a less steep line. Prolongation of these lines results in a point of intersection, and it is the stress at this point that is plotted as the ordinate in Figure 6. For the sample shown by curve A, the yield point started at a low value of 20 grams for zero twist, increased rapidly to a value of about 64 grams at a twist of 6 turns per inch, and levelled off at a value of about 69 grams for twists above 10 turns per inch of yarn. The yarn used for the observations from which curve A was drawn was made by the process of this invention from 150 denier, 40 filament, 0 twist "Acele" (cellulose acetate yarn made by E. I. du Pont de Nemours and Company), using a feed rate of 28.9 yards per minute, an air pressure of 18 pounds per square inch gage, an air flow of 0.49 cubic foot per minute, measured at 760 mm. of mercury pressure and 70° F., and had a final denier of 190. For common textile deniers sufficient resistance to ordinary tensions can be provided by a yield point of at least 0.15 gram per denier, although higher values are preferable.

If desired, yarn of the type shown in Figure 7 may be formed that requires little or no twist to provide relatively high yield points. The reason for the increased stability of this product is the frequent occurrence of snarls formed by entangled loops, e. g., a frequent encircling of the nodes of loops by other loops, most clearly seen at points *a*, *b*, and *c* in Figure 7. An attempt to stretch this modified yarn will cause tightening of many of the encircling loops, thus preventing encircled portions from unlooping, and holding the filament bundle together. As shown by curve B of Figure 6, at zero or low twists the yield point of this yarn is much higher than that of the simple product shown in Figure 5. The yarn tested to determine curve B was prepared from the same 150 denier, 40 filament, 0 twist "Acele" acetate yarn used in connection with curve A, and under identical conditions except that the air pressure was increased to 25 pounds per square inch gage, giving an air flow of 0.55 cubic foot per minute. The final denier was increased to 205 as a result of the more complex yarn structure shown in Figure 7.

Yarn having the snarled or entangled loop structure is produced by a compounding of the ordinary looping action. This may be brought about in any one or more of a number of ways such as increasing the length of time the yarn is within the turbulent zone, increasing the turbulence in the zone, or setting up variations in the extent of turbulence. Adjustment of conditions to vary the bulky yarn produced according to this invention from the form shown in Figure 5 to the more complex structure of Figure 7, or to any intermediate configuration, must be determined by experiment in a particular case.

In the process of this invention it is only necessary for the yarn to be passed through a zone of sufficient turbulence for a sufficient distance to separate the filaments and form them into the described convolutions. The yarn need not be passed through an air jet or nozzle of the types described, but can be passed through a turbulent stream, however formed. Likewise, air need not be used as the turbulent medium; other gases or liquids can be used. Piezoelectric or magnetostrictive transducers might be employed with similar effect, but the fluid jet method is so inexpensive and easy to install, operate and maintain that it is naturally preferred, as the best known mode of operation.

The extremely simple air nozzle **27**, shown in Figure 1, is adequate to accomplish effective yarn treatment as described above. However, smoother operation and more efficient use of air is provided by the modification shown in Figure 8, in which a stream-lined air nozzle **41** is provided in place of the simple yarn tube **29** of Figure 1. Automatic threading or stringing up is assured by addition of yarn guiding member **42** having a conical inner end **43** through which the yarn end can be introduced into the air stream in position to be carried with the air through nozzle **41**. This member is threaded at **44** into a supporting body **45**, providing for adjustment of the distance between cone end **43** and inlet end of air nozzle **41**. Air is fed to the nozzle through pipe **28**.

In the nozzle shown in Figure 9, the air is introduced into a central chamber **49** within the nozzle, passes from the chamber through a helical passageway formed by screw member **50**, which gives the air a swirling motion, and leaves the nozzle through an orifice **51**. It is convenient to form this orifice in a plug **52** screwed into the nozzle body. Although not necessary, it is usually desirable to break up and deflect the jetted stream of air, as with a baffle **53**, which is merely a plate bent at right-angles and attached to the nozzle with a screw **54**. The yarn is conducted through screw member **50** to the vicinity of the orifice by a tube **55** and is caught up by the air stream and carried out of the orifice. The best diameters for the tube and orifice will depend on the yarn being treated. For yarn of about 100 to 400 denier, satisfactory diameters are 0.023 inch inside diameter for the tube and about 0.04 inch for the orifice. The screw member **50**, which supports the tube **55**, is threaded into the nozzle body. The clearance between the inner end of the tube and the orifice is adjusted by the distance the screw member is turned, a hex nut **56** being attached or formed integrally on the outer end of the member for this purpose. When a satisfactory adjustment has been found the screw member is locked in position by a hex nut **57**. The outer end of tube **55** is preferably flared to receive the yarn end when stringing-up.

Proper adjustment will make the jet self stringing, i. e., when an end of yarn is placed in the flared inlet of the tube the air stream will provide sufficient vacuum to pull the yarn through the tube and then blow it out of the orifice, greatly simplifying the starting up operation.

A fairly abrupt removal of the yarn from the turbulent region is conducive to formation of a better product. This may be accomplished by guiding or pulling the yarn from the turbulent stream, as described, or the turbulent stream may be diverted from the yarn by suitable means such as a baffle plate having a hole to admit the yarn. The baffle plate **53** in Figure 9 may be provided with a hole through which the yarn is passed, the air stream being deflected aside by the plate. The rate of windup as compared with the rate at which yarn is supplied to the jet, will limit the amount of bulking action possible by restricting the amount of reduction in length which occurs as the loops form.

The process and products of the invention will now be illustrated by the following examples, which are not to be construed as limiting the scope of the invention.

EXAMPLE 1

Apparatus equivalent to that in Figure 1, and using the nozzle shown in Figure 1, was used to process 150 denier, 40 filament, 0 twist, dull "Acele" cellulose acetate yarn. The yarn was unwound for treatment from a spool by the tension created by the fluid jet, with a friction tension device interposed between the spool and the nozzle to limit the yarn speed to approximately 13 yards per minute (calculated from the wind-up speed and ratio of final denier to starting denier). The nozzle was supplied with nitrogen at 150 pounds per square inch gage pressure, giving a gas consumption of approximately 0.4 cubic foot per minute at 760 mm. and 70° F. The yarn was wound up at 10 yards per minute and twisted to 6 turns per inch with an up-twister. The finished bulky yarn had a denier of 195 and the average filament loop size was about 0.5 mm.

The yarn treatment was repeated with different gas pressures and different yarn speeds to show how the size of the filament loops was affected. The changed conditions and the resulting loop sizes are given in Table I. The loop sizes are compared qualitatively because they are difficult to classify numerically. Generally speaking, however, "V. S." (very small) means that most of the loops were less than 0.5 mm. in size, "small" means that the predominating loop size was about 0.40 to 0.75 mm., "medium" means that the predominating loop size was about 0.5 to 1.5 mm., and "large" means that most of the loops were over 1.5 mm. in size.

Table I

EFFECT OF VARYING OPERATING CONDITIONS ON LOOP SIZE

	A	B	C	D
Gas pressure lbs./sq. in. gage	150	150	300	390
Yarn feed yds./min.	54	31	54	54
Yarn wind-up yds./min.	40	18	37	35
Loop size	Large	Medium	Small	V. S.

EXAMPLE 2

Apparatus of the type shown in Figure 1, but using the nozzle shown in Figure 9, was used to process 150 denier, 100 filament, 0 twist, dull "Acele" yarn. The yarn was fed to the air jet at 21 yards per minute and rewound after treatment at 18 yards per minute at a spindle speed of 5800 R. P. M. to impart a Z twist of 9 turns per inch. The air pressure was 5 lbs./sq. in. and the air consumption 0.21 cu. ft./min. The finished yarn had a denier of 175, a tenacity of 0.71, and an elongation of 20.9%. Untreated 8Z twist yarn had a denier of 150, a tenacity of 1.2, and an elongation of 26.

EXAMPLE 3

Apparatus of the type shown in Figure 1, but using the nozzle shown in Figure 9, was used to process 200 denier, 80 filament, 0.32 twist, bright yarn of "Orlon" acrylic fiber. The yarn was fed to the air jet at 27.5 yards per minute and rewound after treatment at 22.8 yards per minute at a spindle speed of 4700 R. P. M. to impart a Z twist of 6 turns per inch. The air pressure was 15 lbs./sq. in. and the air consumption was 0.26 cu. ft./min. The finished yarn had a denier of 258, a tenacity of 1.98 and an elongation of 17.6. Untreated 6Z twist yarn had a denier of 200, a tenacity of 4.0 and an elongation of 19.

EXAMPLE 4

Apparatus of the type shown in Figure 1, but using the nozzle shown in Figure 9, was used to simultaneously blend and process 150 denier, 60 filament, 2S twist, bright textile "Cordura" viscose rayon yarn and 150 denier, 40 filament, 0 twist, dull "Acele" cellulose acetate yarn. The two yarns were unwound from separate spools and fed together to the air jet at 21 yards per minute. The treated blend was rewound at 18 yards per minute and a spindle speed of 5820 R. P. M. to impart a 9Z twist. The air pressure was 10 lbs./sq. in. and the air consumption was 0.25 cu. ft./min. The finished yarn blend had a denier of 342, a tenacity of 0.74, and an elongation of 12.7. A similar blend which had not received the bulking treatment had a denier of 300, a tenacity of 1.27 and an elongation of 16%.

In Examples 1 to 4 the treatment increased the denier by 30.0%, 16.7%, 29.0% and 14.0%, respectively. This is some indication of the extent to which filaments have been formed into convolutions, but does not indicate the surprising increase in bulk which these convolutions impart to the yarn by maintaining the filaments in spaced relationship. In general, this increase in bulk is at least 80% for packaged yarn, as shown by the following two examples:

EXAMPLE 5

Apparatus of the type shown in Figure 1, but using the nozzle shown in Figure 8, was used to process 75 denier, 30 filament, 0.3Z twist, bright yarn of "Orlon" acrylic fiber. The yarn was fed to the air jet at 54.0 yards per minute, treated with air supplied at 80 lbs./sq. in., and rewound after treatment at 45.0 yards per minute with a 3S twist. The yarn was wound on a quill adapted for accurate measurement of volume at a tension of 20 grams. The yarn bulk was 3.3 cc./gm. as compared with 1.2 cc./gm. for the untreated yarn, or an increase in bulk of 175%. The bulk was markedly superior to that of otherwise comparable spun stable yarn.

EXAMPLE 6

Apparatus of the type shown in Figure 1, but using the nozzle shown in Figure 8, was used to process 150 denier, 0 twist dull "Acele" cellulose acetate yarn. Two plies of this yarn were fed simultaneously to the air jet at 21.6 yards per minute, treated with air supplied at 10 lbs./sq. in., and the combined treated yarn was rewound at 18.0 yards per minute with an 8Z twist under a tension of 68 grams. The yarn bulk was 2.0 cc./gm. as compared with 1.1 cc./gm. for the untreated yarn, or an increase in bulk of 82%, even though the yarn was wound under considerable tension.

Since the purpose in treating yarn in accordance with this invention is to improve properties of fabrics in which it is used, the most practical way of showing the increase in bulk achieved is by observation made on such fabrics.

EXAMPLE 7

Fabrics were prepared in a 2 x 2 twill weave from untreated continuous filament viscose rayon yarn, from bulky yarn produced by treating the yarn in accordance with this invention, and from staple yarn spun from cut filaments. A comparison of the results is given in Table II. The bulk was measured by ASTM method D-76-49 at 3 lbs./sq. in., with an Ames gage.

Table II

COMPARISON OF FABRICS WOVEN FROM THREE VISCOSE RAYON YARNS

Type of yarn	Denier of yarn	Fabric count	Thickness in inches	Weight, oz./sq. yd.	Bulk, cc./gm.
Untreated	300	63 x 60	0.013	5.01	1.9
Treated	340	64 x 68	0.021	5.95	2.6
Spun staple	313	68 x 62	0.0195	5.65	2.6

EXAMPLE 8

Plain weave fabrics of comparable count were prepared from untreated continuous filament yarn made of "Orlon" acrylic fiber, from bulky yarn produced by treating the same yarn in the manner described in the previous examples, and for staple yarn spun from cut filaments. The fabric bulk was determined by ASTM method D-76-49 using an Ames gage at a pressure of 3 lbs./sq. in. A comparison of the results is given in Table III.

Table III

COMPARISON OF FABRICS WOVEN FROM THREE DIFFERENT YARNS OF "ORLON" ACRYLIC FIBER

Type of yarn	Denier of yarn	Fabric count	Thickness in inches	Weight, oz./sq. yd.	Bulk, cc./gm.
Untreated	100	81 x 72	0.006	2.12	2.1
Treated	125	80 x 64	0.015	2.36	4.8
Spun staple	133	93 x 60	0.0125	3.32	2.8

The results of Examples 7 and 8 show the marked superiority in bulk of fabrics woven from the yarn of this invention in comparison with fabrics woven from ordinary continuous filament yarn. In general the increase in bulk is at least 30% when measured under the severe conditions described. The results also show that the bulky yarn may be equal, or even markedly superior, to spun yarn in this respect. The way in which the filaments are spaced is shown visually in Figure 10. Fabric woven of bulky yarn was immersed in methyl methacrylate and the monomer was polymerized to hold the filaments in position. Then a cross-sectional slice 50 microns thick was cut from the fabric. The slice was too thin to show the filament convolutions as such, but the reproduction of a photomicrograph of the slice in Figure 10 clearly shows the effect which the convolutions have in keeping the filaments spaced apart. Intersections of loops with the plane of the cut appear as irregularly shaped dots.

Bulky yarn can be prepared by the process of this invention from any continuous textile fibers regardless of their origin. However, since the filament convolutions of each filament are held in place by adjacent filaments, the process is operative only with multifilaments. The minimum number of filaments which can be processed satisfactorily into bulky yarn varies with the fiber, depending upon such factors as smoothness of surface, denier per filament, and the bending modulus, but any of the continuous multifilament materials referred to as yarn in the textile trade can be prepared in this bulk form. The process described has been applied successfully to the production of bulky yarn from a wide variety of commercial fibers, as indicated in Table IV. In this table the starting material is designated by numbers indicating the yarn denier, the number of filaments and the twist in turns per inch, respectively, the type of twist, if any, and the trade designation. The designation "nylon" refers to polyhexamethylene adipamide and "polythene" refers to polymerized ethylene fibers. "Orlon," "Acele," and "Dacron" are trademarks of E. I. du Pont de Nemours and Company for acrylic, cellulose acetate and polyester fibers, respectively. "Vinyon" N is a vinyl chloride-acrylonitrile copolymer produced by Union Carbide and Carbon Corp. "Fortisan" is a high tenacity rayon regenerated by saponification of cellulose acetate and produced by the Celanese Corporation of America. "Fiberglas" is spun glass produced by Owens-Corning Fiberglas Corp. The nozzle shown in Figure 8 was used in the examples of Table IV, with the indicated air pressure given in lbs./sq. in. gage. The air consumption is in cu. ft./min. at 760 mm. and 70° F. Yarn speed is in yards per minute.

Table IV

BULKY YARN PREPARATION FROM VARIOUS MATERIALS

Ex. No.	Starting material	Yarn speed		Air pressure	Air consump.	Final denier
		Feed	Windup			
9	70-34-½Z Nylon; 150-40-0 "Acele"	50	35	52	0.68	286
10	70-34-½Z Nylon; 75-30-0 Visc. Rayon	50	41	52	0.68	169
11	70-34-½Z Nylon; 75-30-0 Visc. Rayon	82	66	52	0.66	161
12	70-34-½Z "Dacron"	50	38	48	1.20	80
13	40-34-½S "Dacron"	31	26	52	0.88	50
14	40-34-½S "Dacron"	25	19	49	1.24	54
15	40-34-½S "Dacron"; 150-40-0 "Acele"	24	18	50	1.25	247
16	40-13-½Z Nylon; 150-40-0 "Acele"	24	18	50	1.25	240
17	40-13-½Z Nylon; 150-40-0 "Acele"	150	112	50	0.71	212
18	40-13-½Z Nylon	50	36	40	1.06	46
19	300-80-0 "Acele"	48	41	50	1.18	359
20	300-50-0 Visc. Rayon	48	41	50	1.18	345
21	300-120-0.3Z "Orlon"	48	41	50	1.18	354
22	280-136-½Z Nylon	48	41	52	1.19	340
23	289-136-½Z "Dacron"	48	42	60	1.25	301
24	100-60-0 Visc. Rayon; 150-40-0 "Acele"	38	26	68	1.28	319
25	70-34-½Z Nylon; 100-60-0 Visc. Rayon	38	26	68	1.38	203
26	100-40-0.3Z "Orlon"; 100-60-0 Visc. Rayon	38	26	68	1.28	243
27	100-60-0 Visc. Rayon; 70-34-½Z "Dacron"	38	26	68	1.28	201
28	Raw China Silk	21	19	76	1.34	149
29	130-160-3Z "Vinyon" N	24	18	50	1.21	164
30	90-120-3Z "Fortisan"	21	17	43	1.11	106
31	108-60 Casein	21	18	50	0.93	130
32	110-115 "Fiberglas"	21	20	70	1.30	112
33	66-20-7Z Polythene	21	18	41	1.07	76

The advantages of this invention are many. The bulky yarn has the desirable properties of spun staple yarn and avoids the necessity of cutting continuous filaments into staple and then reforming the staple into yarn. The bulky yarn is simply and economically prepared, by a process which requires little equipment, directly from the continuous filament bundle initially produced in synthetic-fiber manufacture. The bulky yarn is superior to spun staple for many purposes because of its freedom from loose ends. However, it can be made to resemble spun staple in this respect, if desired, by cutting or singeing the protruding filament loops to provide loose ends. The unmodified hand of fabrics made from the bulky yarn usually is stiffer than that of corresponding staple materials, making them more suitable for use in draperies, suits, overcoats, etc.

The yarn is sufficiently uniform to be handled easily by textile machinery and to form highly uniform fabrics without the sacrifice of bulk or of fiber interlocking characteristic of some mechanically crimped yarn having too regular a structural pattern. The yarn has been used without difficulty on both automatic weaving and automatic knitting machines. The increased covering effectiveness of fabric made with the bulky yarn permits the production of more fabric from the same weight of yarn and, in addition, by greatly extending the utility of artificial fibers, enables them to replace expensive or scarce fibers in many uses.

Another advantage is the suitability of this process to combining filaments of extremely fine denier into light bulky yarns, having a highly uniform appearance, for which there is no spun staple counterpart. More than one kind of filament may be processed simultaneously to create yarns with a desirable blend of fiber characteristics. Intermittent impulsing of the multifilament being processed can be used to produce a novelty yarn having alternating smooth lengths and bulked regions produced according to the described process.

The simplicity of the new process permits its use at any point in yarn manufacturing or winding with no interruption of processing routine and little outlay for new equipment. Distinct advantages of the process are that it requires little supervision, demands very little maintenance because of its freedom from moving parts, and does not involve temperature or humidity control.

Since many different embodiments of the invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited by the specific illustrations except to the extent defined in the following claims.

What is claimed is:

1. A bulky yarn comprising a plurality of substantially continuous filaments which are individually convoluted into coils, loops and whorls at random intervals along their lengths, and characterized by the presence of a multitude of ring-like loops irregularly spaced along the yarn surface.

2. A bulky continuous filament yarn comprising a plurality of filaments which are individually looped upon themselves at random intervals along their lengths into a multitude of crunodal loops irregularly spaced on different filaments.

3. A bulky continuous filament yarn characterized by having a multitude of ring-like filament loops irregularly spaced along the yarn surface and having a multitude of filament convolutions irregularly scattered through the yarn structure providing a bulk-giving lateral interfilament spacing.

4. A bulky continuous filament yarn having a multitude of crunodal filament loops of less than 1 millimeter in size irregularly spaced on different filaments and scattered through the yarn structure.

5. A bulky continuous filament yarn having a multitude of crunodal filament loops which are at random intervals along the individual filaments, irregularly spaced on different filaments, scattered through the yarn structure and held in place by adjacent filaments.

6. A bulky continuous filament yarn having a multitude of crunodal filament loops which are at random intervals along the individual filaments, irregularly spaced on different filaments, scattered through the yarn structure and held in place by a twist imparted to the yarn.

7. A bulky continuous filament yarn having a multitude of crunodal filament loops which are at random

intervals along the individual filaments, irregularly spaced on different filaments, and scattered through the yarn structure and further characterized by frequent occurrence of snarls formed by entangled filament loops.

8. A bulky continuous filament yarn having a multitude of crunodal filament loops which are at random intervals along the individual filaments, irregularly spaced on different filaments, and scattered through the yarn structure, said yarn having a yield point of at least 0.15 gram per denier.

9. A bulky continuous filament yarn having a multitude of crunodal filament loops which are at random intervals along the individual filaments, irregularly spaced on different filaments, and scattered through the yarn structure, sufficient twist being imparted to the yarn to provide a yield point of at least 0.15 gram per denier.

10. A bulky continuous filament yarn having a multitude of crunodal filament loops which are at random intervals along the individual filaments, irregularly spaced on different filaments, and scattered through the yarn structure, and having a sufficiently frequent occurrence of snarls formed by entangled filament loops to provide a yield point of at least 0.15 gram per denier for zero twist yarn.

11. A bulky continuous filament yarn comprising a plurality of substantially continuous filaments which are individually convoluted at random intervals along their lengths into crunodal loops which are irregularly spaced on different filaments and which loops substantially disappear when the yarn is pulled apart.

12. A bulky continuous filament yarn composed of a plurality of filaments which are individually looped upon themselves at random intervals along their lengths into a multitude of crunodal loops irregularly spaced on different filaments and having at least 80% greater bulk as packaged yarn than yarn composed of the same number of filaments which differ only in being straight.

13. A bulky continuous filament yarn composed of a plurality of filaments which are individually looped upon themselves at random intervals along their lengths into a multitude of crunodal loops irregularly spaced on different filaments, and having a denier at least 10% greater than the denier of yarn composed of the same number of filaments which differ only in being straight.

14. A bulky continuous filament yarn having the superficial appearance of staple yarn and having a bulkiness at least as great as that of staple yarn of the same overall denier spun from staple fiber of the same denier and composition as the filaments making up the bulky yarn, said bulky yarn being composed of substantially continuous filaments which are individually convoluted at random intervals along their lengths into crunodal loops which are irregularly spaced on different filaments.

15. A textile material composed of a plurality of continuous filaments and filled with voids formed by a multitude of crunodal filament loops which are at random intervals along the individual filaments, irregularly spaced on different filaments, scattered through the material and held in place by adjacent filaments.

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