July 10, 1962 A. L. BREEN 3,043,088

PROCESS FOR MAKING BULKY YARN

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Fig. 1

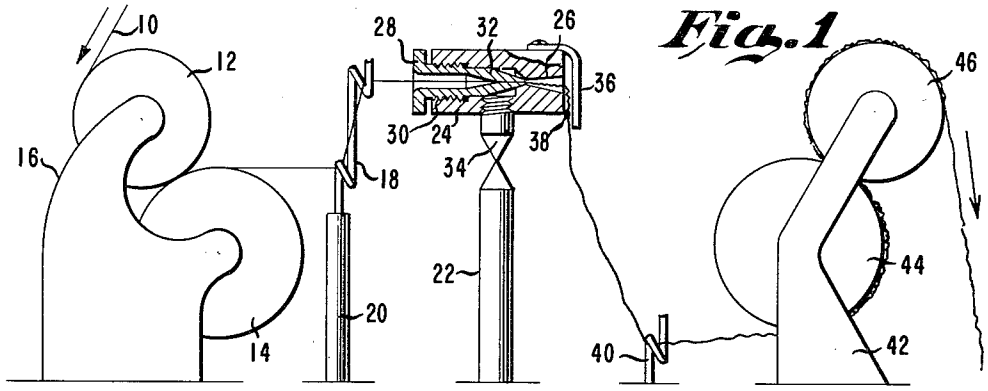


Fig. 2

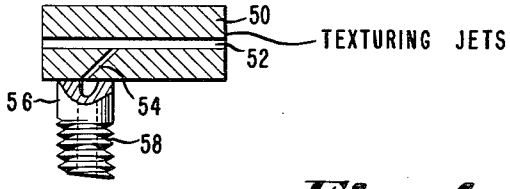


Fig. 3

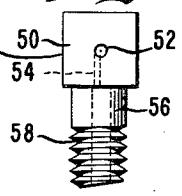


Fig. 4

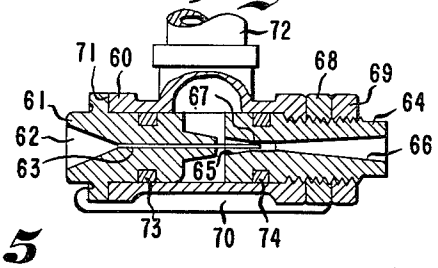


Fig. 5

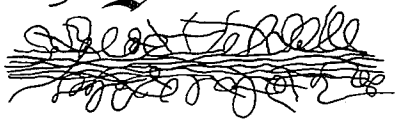


Fig. 6

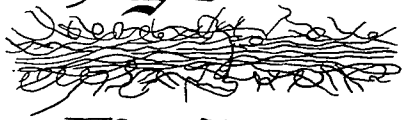


Fig. 7

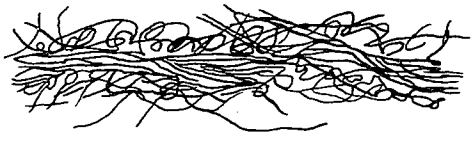


Fig. 8



Fig. 9



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Fig. 10

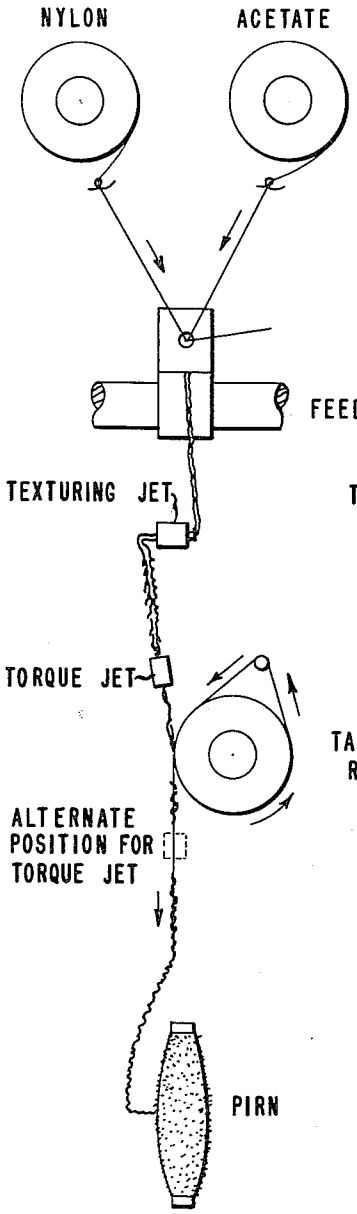


Fig. 11

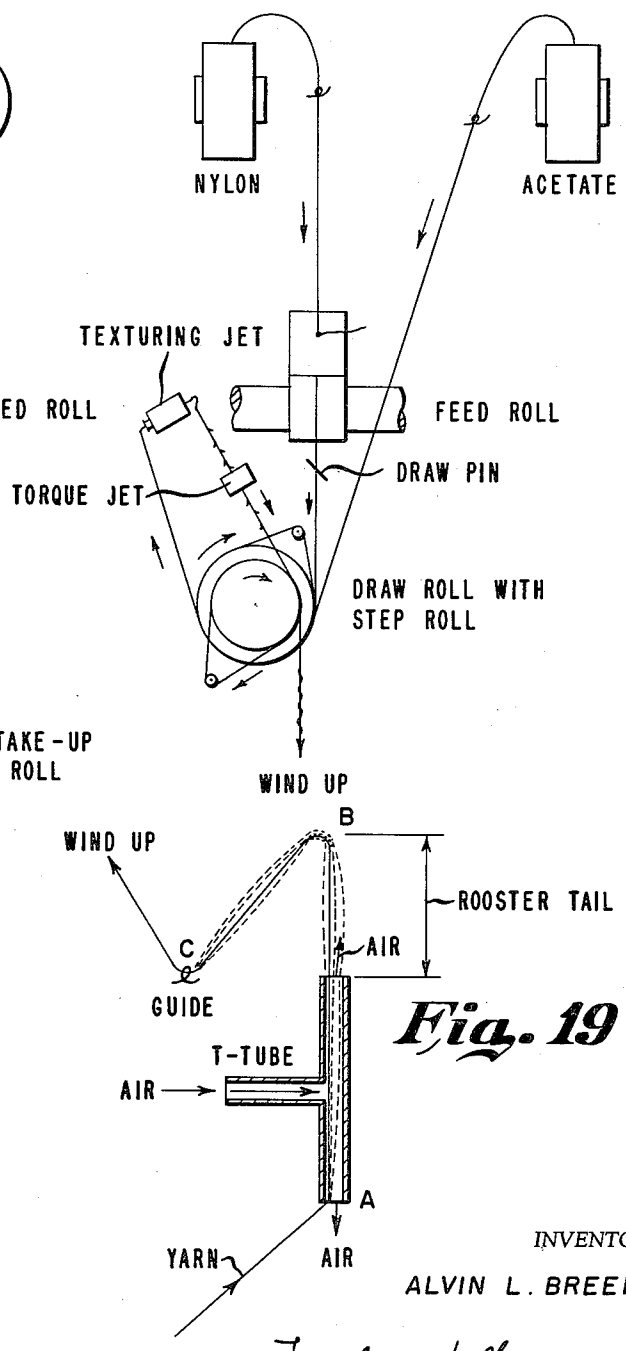


Fig. 19

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Fig. 12

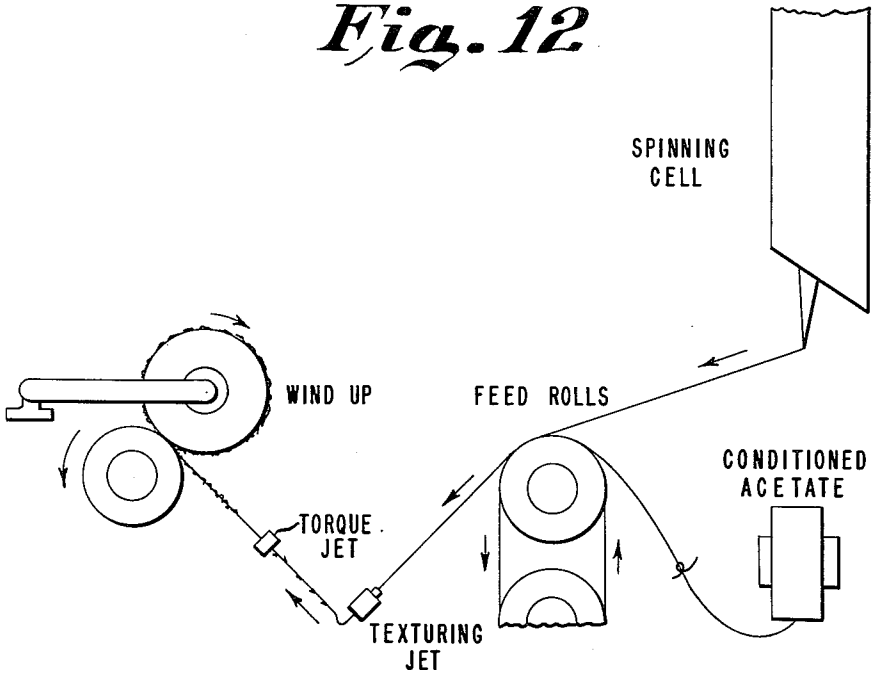
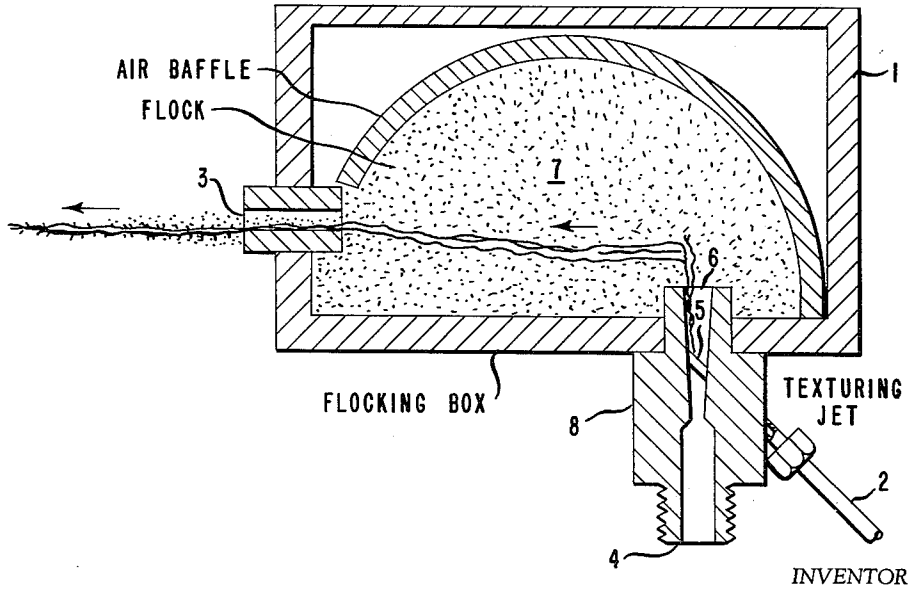


Fig. 13



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Fig. 14

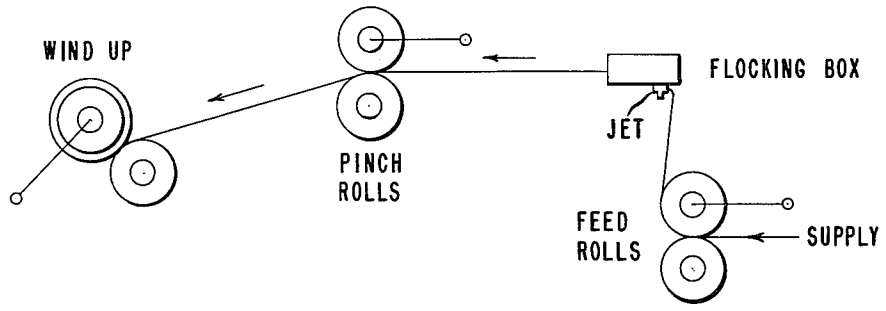


Fig. 15

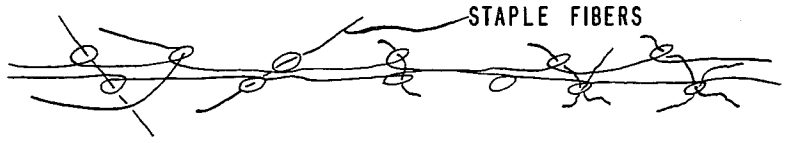


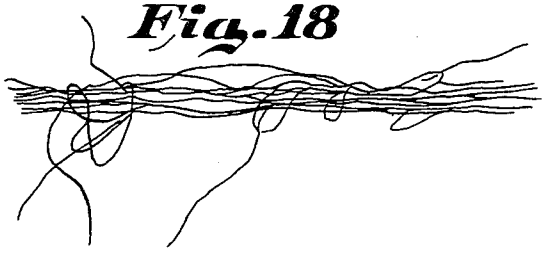
Fig. 16



Fig. 17



Fig. 18



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United States Patent Office

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Patented July 10, 1962

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PROCESS FOR MAKING BULKY YARN

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Filed Nov. 25, 1958, Ser. No. 776,566
17 Claims. (Cl. 57—157)

This invention relates to treatment of yarn, or thread, to produce yarn of greatly increased bulk, and is more particularly concerned with the production of a bulky yarn composed of plurality of individually convoluted fibers and characterized by the presence of a multitude of ring-like loops and protruding fiber ends irregularly spaced along the yarn surface.

In my copending application, Serial No. 261,635, filed Decembr 14, 1951, now Patent No. 2,783,609 I disclose the production of a novel bulky filament yarn having most of the desirable properties of ordinary spun staple yarn, but differing in being composed of substantially continuous filaments. In that yarn, bulk and an appearance resembling that of staple yarn is provided by a multitude of ring-like loops and other convolutions at random intervals along the filaments and irregularly spaced on different filaments. While this continuous filament structure is a distinct advantage for most purposes, there are textile uses which require a fuzzy, lofty or cashmere-like effect provided by a yarn which has a large number of protruding filament ends. A yarn having the combination of properties provided by free ends and bulk-giving filament convolutions would be desirable for such uses.

With the exception of silk, natural animal, vegetable and mineral fibers exist only in relatively short lengths. Yarn prepared from these natural fibers necessarily is composed of staple length fibers. Furthermore, large quantities of artificial continuous filaments are cut into staple before processing into yarn. Treatment of these staple yarns to introduce bulk-giving convolutions would be desirable regardless of whether or not free ends are required. When the desired effect requires protruding ends it would be highly desirable to provide a process for treating continuous filament yarn to impart both bulk and a multitude of protruding ends in one operation, thereby avoiding the expensive operations of cutting continuous filaments into staple and spinning the staple into yarn.

An object of this invention is to provide a yarn which has a large number of protruding free ends of fiber and has an enhanced bulk provided by filament convolutions of the type characterized by the presence of ring-like loops. Another object is to provide a spun staple yarn of improved bulk characterized by the presence of a multitude of ring-like loops and protruding fiber ends irregularly spaced along the yarn surface. A further object is to provide a process for preparing yarn of improved bulk from conventional spun staple yarn. An additional object is to provide a process for treating continuous filament yarn to provide greatly increased bulk and a covering of projecting fiber ends in one operation. Other objects of the invention will become apparent from the following description and claims.

In the drawings, which illustrate preferred embodiments of the invention,

FIGURE 1 is a side elevation of suitable apparatus for practicing the process of this invention,

FIGURE 2 is a side elevation, partially in section, of an alternative form of nozzle,

FIGURE 3 is an end view of the nozzle shown in FIGURE 2,

FIGURE 4 is a side elevation, partially in section, of another form of nozzle,

FIGURE 5 is a side view showing the appearance of

untwisted treated yarn prepared from continuous filament yarn (enlarged about ten times),

FIGURE 6 is a similar enlarged view of untwisted treated yarn prepared from two plies of continuous filament yarn,

FIGURE 7 is a similar enlarged view of treated yarn prepared from a ply of continuous filament yarn and a ply of cotton yarn,

FIGURE 8 is a similar enlarged view of a treated yarn prepared from a single ply spun staple yarn,

FIGURE 9 is a similar enlarged view of a treated yarn prepared from a two ply spun staple yarn,

FIGURE 10 is a schematic view of the arrangement of the yarn feed, texturing jet, torque jet, take-up roll and wind-up,

FIGURE 11 is a schematic view of an alternate arrangement similar to FIGURE 10 but includes a draw roll with a step roll and a draw pin,

FIGURE 12 is a self-explanatory alternate arrangement of FIGURE 10,

FIGURE 13 is a diagrammatic section of a flocking box provided with a texturing jet,

FIGURE 14 is a schematic view of an arrangement of yarn feed rolls, flocking box, pinch rolls and wind-up,

FIGURE 15 illustrates diagrammatically in isolated strands how the staple fibers are caught in loops introduced by a jet,

FIGURE 16 shows the staple secured in the loops of FIGURE 15 which have been drawn to lock the staple fiber in place,

FIGURE 17 shows the staple fiber flattened back against the load-bearing fiber in an isolated strand,

FIGURE 18 illustrates how some strands are wrapped around the filament bundle by the torque jet, and

FIGURE 19 represents a modification in which a T-shaped tube is used in place of the texturing jet. The T tube may be made of any smooth material such as glass, stainless steel, or the like, and may vary in diameter from about ⅛" to ½".

In accordance with this invention a novel yarn is provided which has a fuzzy to cashmere-like appearance resulting from a covering of projecting fiber ends and unusual bulk, as compared with staple yarns of the prior art, resulting from fibers which are convoluted into coils, loops and whorls at random intervals along their lengths and at irregular spacing on different fibers to provide a lateral interfiber spacing. The most obvious characteristics of the yarn are the combination of unusual bulkiness with the fuzzy covering provided by protruding fiber ends, but the yarn is also characterized by the presence of a multitude of ring-like loops and other convolutions in the fibers. The convolutions visible on the surface contribute desirable properties to the yarn, but the less obvious fiber convolutions within the yarn are even more important in producing bulk and resulting garment warmth of fabrics made from this yarn.

The characteristic loops in the yarn fibers have been described as "ring-like" because they are tiny complete loops formed by a fiber 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 characteristic loops will be more specifically defined as "crunodal loops," and loops of this type are intended unless otherwise indicated in the following specification and claims. The majority of loops visible on the surface of the yarn are of a roughly circular shape and are properly described as ring-like. 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 fiber ends and convolutions may be held in

place by a twist imparted to the yarn. A single ply yarn may have a Z or an S twist. In a multiple ply yarn the individual plies are usually twisted in one direction and the plurality of plies are usually twisted together in the opposite direction, e.g., the plies may have a Z twist and the yarn may have an S twist. Unless the convolutions have been set, as by heating the convoluted yarn, the fibers will resume their original unconvoluted condition when the yarn is untwisted and taken apart; hence initially straight fibers will be recovered in a substantially straight condition. Of course, if the yarn fibers were initially crimped or wavy or curly, they would resume that condition on being separated from the yarn.

The yarn of this invention is prepared by a process which involves feeding yarn through a high velocity fluid jet, under conditions adapted to accomplish the double purpose of imparting bulk-giving convolutions and of providing a multitude of projecting filament ends, and then twisting the filaments together to hold the convolutions and filament ends in place. In some respects the process resembles that of my copending application, Serial No. 261,635, now Patent No. 2,783,609. However, additional critical conditions must be observed to provide the desired covering of filament ends on the yarn surface.

The starting yarn may be composed of substantially continuous filaments or of staple length fibers, which may be natural fibers or artificial filaments cut to staple length, or the yarn may include two or more of these types.

When treating yarn composed of substantially continuous filaments in accordance with this invention, the yarn is fed through a jet operated under conditions such that the filaments are shattered at random intervals to provide the desired free ends of projecting fiber. In order to accomplish this, the jet must first open up the yarn. The filaments of an untwisted continuous filament yarn are readily separated by the turbulence created by a high velocity jet. Twisted yarn must be untwisted before the filaments can be separated, but this action can also be achieved by the jet. Under proper conditions the jet will apply sufficient false untwisting to the yarn filaments to permit the jet to open up the yarn, and this is true not only when the yarn is composed of a single twisted ply, but also when it is composed of a plurality of plies which are individually twisted. Once the yarn filaments are separated, suitable jet turbulence will whip the filaments about with such rapidity that the flex life of the material is quickly exceeded and some or many of the filaments are broken.

Operation of the jet at approximately sonic velocity, or near sonic velocity, will accomplish these objectives of opening up the yarn and whipping the filaments about sufficiently to shatter them into relatively short lengths. The distance the yarn travels through the jet should be less than the average length of the fibers produced by this shattering of continuous filaments, so that the fibers will not be removed from the yarn to an objectionable extent. After the yarn is withdrawn from the jet it is twisted to hold the resulting fibers and convolutions in place. The severity of the shattering effect will vary with the flex life of the filament material, under otherwise similar conditions, but the structure resulting from the treatment can be controlled by the rate at which the yarn is passed through the jet.

Preparation of the yarn of this invention from staple yarn is simpler in at least one respect, since filament-shattering is not required, but unexpected difficulties must be overcome or else the yarn is either torn to pieces or is substantially unaffected by the treatment. The fibers of staple yarn must be held in place by a twist in the yarn, but the yarn must be untwisted while in the jet for the treatment to have appreciable effect. At near sonic velocities the jet has been found to apply a substantial untwisting torque as well as considerable tension to the yarn. If the yarn is permitted to untwist in response to this torque for a distance which exceeds the fiber length, the

draft yield strength of the yarn is reduced to such an extent that the accompanying jet tension is sufficient to pull the yarn apart. When the yarn is fed through the jet to a windup, it has been found that the untwisting action of the jet is limited to the length of yarn between the feed and windup devices. In other words, the jet torque applies a false untwist to the yarn. The extent of this false untwisting action is inversely proportional to the tension applied to the yarn between feed and windup, since tension imposes a torque which opposes the jet torque. Hence the false untwist can be controlled by increasing the tension, but this does not solve the difficulty because the total of the jet tension and windup tension then exceeds the yarn strength.

In accordance with this invention it has been found that yarn which consists wholly or in part of staple-length fibers held in place by a yarn twist can be processed efficiently when feeding the yarn to a high velocity fluid jet operated to apply a false untwist to the yarn, by snubbing the yarn passing to the jet to prevent the untwist from backing up, and again snubbing the yarn leaving the jet to prevent the untwist from carrying forward, the distance between the two snubbing points being less than the length of the staple fibers and preferably being arranged to restrict the false untwist to an effective distance of less than one-half the length of the staple fibers. The required snubbing may be accomplished by dragging the yarn over fixed surfaces, which may be the yarn entrance and exit surfaces of the jet nozzle. The yarn leaving the jet can be snubbed by directing it against a baffle plate which also serves to remove the yarn from the jet stream.

The action of the jet in untwisting the yarn may be likened to a combing action. The pull of the jet stream acts to straighten the helically twisted fibers, creating a torque which untwists the yarn. A jet operated at near sonic velocity provides sufficient torque to untwist the yarns usually encountered, but it is sometimes desirable, especially with high twist single ply yarn, to provide a rotating torque jet which rotates in the opposite direction from that of the yarn twist to accentuate the false untwisting torque of the jet. Purely mechanical means for applying false twist are known in the art, but are not necessary to accomplish the false untwist described. After the fibers have been untwisted the turbulence of a high velocity jet will act to separate the fibers and form them individually into convolutions with outwardly projecting fiber ends. Both staple yarn and continuous filament yarn can therefore be processed in a similar manner with a near sonic velocity jet to produce the desired bulky yarn having a covering of projecting fiber ends.

Plied yarn can be processed somewhat more readily than single ply yarn because the plies exert a snubbing action on each other which tends to resist untwisting of the fibers. This effect can supply a part or all of the snubbing action required to prevent the region of false untwist from being so extensive that the yarn is pulled apart. This is most easily seen in the case of a plied staple yarn of the usual type in which the singles twist is in one direction, e.g., a Z twist, and the ply twist is in the opposite direction, e.g., an S twist. An untwisting torque applied to the ply fibers also causes the plies to twist together in the opposite direction, which increase of ply twist opposes the above torque and tends to prevent the fibers from being separated for more than a short distance. If the twist is sufficiently great, as in a high twist yarn, this opposition to fiber separation provides all of the snubbing needed and it is not necessary to rely on snubbing surfaces before and after the jet. The same thing is true to a lesser extent when the plies fed to the jet are not twisted together. The plies still provide a snubbing action which opposes forces tending to untwist the fibers of a ply. Thus two separate single ply yarns can be fed to a jet together and processed into a single yarn in accordance with this invention with less difficulty

than a single ply. When one ply is composed of continuous filaments and another ply is composed of staple-length fibers, the continuous filaments also help resist tensions tending to exceed the draft yield strength of the staple ply.

FIGURE 1 shows a suitable arrangement of apparatus for practicing the process of this invention. The starting yarn **10** may be supplied from any convenient source, such as a yarn package, and may come directly from the spinning process by which it is produced without intermediate wind-up. The yarn is passed between feed rolls **12** and **14**, arranged to be driven so as to forward the yarn at the desired speed, which is preferably of the order of 50 to 100 yards per minute but may vary over a wide range. These feed rolls are mounted on a pedestal **16**. The yarn passes through guide **18** on support **20** and into a jet nozzle supported by air supply pipe **22**. The nozzle is shown in section to clarify the construction. The body portion **24** of the nozzle is hollow and is provided with a fluid exit **26** which has a venturi-like shape to create the required high velocity jet. A hollow male member **28** is threaded into the body at **30** and terminates in a cone **32** projecting into the mouth of the jet-forming exit **26**. The yarn passes inside the male member, out through a hole in the projecting cone, and is carried out of the nozzle exit **26** by the jet stream created by air entering the nozzle through pipe **22**. The flow of air to the jet can be regulated by valve **34** in the supply pipe. The yarn hole in cone **32** should be of a size which provides a fairly snug fit around the yarn so that the yarn is snubbed sufficiently to prevent appreciable untwisting before the jet is reached, unless equivalent snubbing is provided by other means.

The yarn leaving the nozzle is deflected at right angles by a baffle plate **36** mounted on the nozzle close to the exit **26**. The baffle plate accomplishes the dual purpose of terminating the action of the high velocity jet on the yarn and of snubbing the yarn against untwisting beyond this point. For reasons previously explained, the distance from the end of the cone **32** to the baffle plate must be less than the length of fibers in the treated yarn, and should preferably be such as to limit the false untwisting action of the jet to less than one-half the fiber length. Instead of the baffle plate, a guide can be used to achieve a similar result. Frequently sufficient snubbing can be accomplished by pulling the yarn across exit face **38** of the nozzle. When sufficient back snubbing is not provided by the yarn hole in cone **32** the yarn can be fed into the nozzle at an angle so that the yarn is snubbed against other parts of the male member **28**.

The jet stream is operated at a near sonic velocity to separate the fibers, form them into bulk-giving convolutions, and cause fiber ends to project from the yarn, all as described previously. The treated yarn now passes through a guide **40** located below baffle **36**, and then to a pair of take-up rolls **44** and **46**, which are suitably supported on pedestal **42** and are driven at a surface speed somewhat less than that of feed rolls **12, 14** to provide an overfeed to the jet. The amount of overfeed is one of the factors controlling the amount of bulking action accomplished in the jet and should generally be in the range of 5% to 50%, depending upon the effect desired. The percent overfeed is the percent by which the speed of yarn feed to the jet exceeds the take-up speed. The take-up rolls **44, 46** may feed to any suitable wind-up or, alternatively, one of these rolls can be a wind-up roll.

A variety of nozzles can be used instead of the one illustrated in FIGURE 1 to provide the required jet. A simple alternative form is shown in FIGURES 2 and 3. A metal block **50** is drilled lengthwise to provide axial yarn passage **52**. An air entrance **54** is drilled at a forward angle of about 45° through one face of the block to intercept the yarn passage. When a rotating jet stream is desired the air entrance may be made of smaller diameter than the yarn passage and be off center to intercept the yarn passage at one side as shown in FIGURE 3. Fitting **56** is soldered over the air entrance; it is threaded at **58** for attachment to the air supply pipe **22** of the apparatus shown in FIGURE 1. In place of air other fluids can be used such as CO_2, steam, or other vapors for special purposes.

The nozzle shown in FIGURE 4 provides advantages over the two forms already described. The housing **60** may be a standard ¼ inch plumber's T. The yarn enters through guide member **61**, provided with a funnel-shaped portion **62** to receive the yarn end when stringing up. A hypodermic needle **63** of appropriate size provides a passage for conducting the yarn into the nozzle **64**. The nozzle has the shape of a conventional venturi tube with the entrance **65** tapering inward so that opposite sides are at about a 20° angle with each other, and the exit **66** diverging more gradually so that opposite sides are at about a 7° angle with each other. The overall length of the venturi tube may suitably be about 1.3 inches with the diverging exit portion about 1.0 inch long. The arrangement of guide member **61**, needle passage **63** and nozzle **64** makes the device self-stringing when a yarn end is fed to it.

The needle **63** is adjusted to extend into the entrance of the venturi and stop in the venturi throat **67**. This adjustment is important for best performance. The manner of adjustment shown is to thread the outside of the nozzle and provide positioning and locking nuts **68, 69**. The nozzle slides with a snug fit into the housing **60** until nut **68** rests against the housing. It is held in this position by springs, one of which is indicated at **70**. The guide member **61** likewise slides into the housing with a snug fit until shoulder **71** is positioned against the housing. It may also be held in position by spring **70** and other similar springs. Advantages of this construction are that it can be taken apart easily for cleaning and the parts can be rotated to adjust the needle in the venturi throat. However, either or both parts may be held in position by set screws passing through the housing, or the parts may be threaded into the housing.

Air is supplied to the nozzle through pipe **72**, which is threaded or soldered into the T housing. The air passes through the venturi around the needle **63**, the venturi throat **67** being sufficiently larger than the needle to permit passage of the required volume of air. Gasket material may be placed in groove **73** around member **61** and groove **74** around the nozzle to prevent air leakage.

In FIGURE 13, **1** represents a flock chamber provided with an inlet **2** and an exit **3** for the yarn. Between the inlet and exit is an open space containing flock **7**. The chamber is also provided with an internal air baffle. The air supplied through the texturing jet keeps the flock or linters in a state of violent agitation. The inlet **2** is usually through a texturing jet which is provided with an air supply **4** and an outlet **5** at the base of a venturi chamber **6**.

The yarn is led through the inlet **2** where it is subjected to a high speed air jet which textures the yarn forming whorls and loops. As the yarn passes through the suspended flock **7**, the fibers find their way into the interstices and loops of the yarn where they are held and entrained as the yarn passes through the exit **3** of the flocking chamber **1**. The yarn then proceeds as shown in FIGURE 14.

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

The apparatus shown in FIGURE 1 was used to process a single ply of 150 denier, 40 filament, 0 twist, continuous filament cellulose acetate yarn. This yarn was fed to the nozzle at 60 yards per minute and taken up after treatment at 40 yards per minute, an overfeed of 50%. Air was supplied to the nozzle at 90 pounds per square inch gage pressure to give the effective jet velocity of slightly greater than sonic, and an air flow through the nozzle

of 2.6 cubic feet per minute measured as "free" air at atmospheric pressure and temperature. The baffle plate was spaced ⅛ inch from the nozzle exit. The appearance of the untwisted treated yarn is shown in FIGURE 5. The filaments were convoluted and partially shattered to provide a multitude of filament loops and protruding ends as shown. This yarn was rather weak.

Two plies of the above yarn were fed together to the nozzle at 19 yards per minute and taken up after treatment at 14 yards per minute, an overfeed of 36%. The other conditions were the same as above. FIGURE 6 shows the appearance of this two-ply yarn after treatment, which exhibited the characteristic fiber loops and ends described above. When twisted the yarn was reasonably strong and processed satisfactorily into fabric.

Operation of the process as above, but without the baffle plate, or with the baffle plate spaced one inch or more from the nozzle exit, resulted in the yarn being completely shattered into flock. Operation of the process as above, but at air pressures of 40 pounds per square inch to give air flows of less than 1.0 cubic feet per minute, measured as free air, produced bulk-giving convolutions without appreciable filament shattering, whereas pressures of 50 or more pounds per square inch produced the multitude of filament loops and ends described above.

EXAMPLE 2

Using the apparatus shown in FIGURE 1, two separate plies of yarn were fed to the nozzle. One ply was a 20 cotton count, 15 **Z** twist (15 turns per inch) cotton yarn. The other ply was a 200 denier, 80 filament, continuous filament acrylonitrile yarn. The yarns were fed into the nozzle together at 10 yards per minute. Air was supplied to the nozzle at 90 pounds per square inch gage pressure, which gave a flow, as free air, of 2.7 cubic feet per minute. The appearance of the resulting two-ply yarn after receiving a slight twist is shown in FIGURE 7. The bulk of both plies was markedly increased by the formation of crunodal loops and other convolutions, and cotton fibers were caused to project with a great increase in fuzziness. The cotton ply was extended in length by the treatment, so that it wrapped around the continuous filament ply when the yarn was twisted.

An attempt to treat the cotton yarn alone under similar conditions, but without the baffle plate, resulted in the yarn being completely blown apart and reverted to unspun staple. The same was true even under such relatively mild conditions as 50 pounds per square inch air pressure and 10% overfeed; the cotton yarn was disintegrated.

EXAMPLE 3

A single ply, 18 cotton count, 18 **Z** twist spun yarn composed of 3-inch staple length, 3 denier, acrylonitrile fibers was processed with an apparatus similar to that shown in FIGURE 1. The yarn was taken up from the nozzle at 15 yards per minute and the baffle plate was located ¾ inch from the snub point provided by the restricted yarn passage into the jet stream. Air was supplied to the nozzle at 90 pounds per square inch gage, the nozzle dimensions being such as to give a flow of about 1 cubic foot per minute with an effective jet stream velocity of slightly above sonic velocity. The appearance of the treated yarn is shown in FIGURE 8. The yarn was greatly increased in bulk and the surface was covered with ring-like loops and extending fiber ends, giving the yarn a fuzzy or lofty appearance and feel.

EXAMPLE 4

A single ply, 18 cotton count, 14 **Z** twist spun yarn composed of 4½ inch staple length, 3 denier, acrylonitrile fibers was processed at about 100 yards per minute and 10% overfeed using an air pressure of 50 pounds per square inch gage. The apparatus was similar to that shown in FIGURE 1, except that the nozzle shown in FIGURE 4 was used without a baffle plate and yarn guide **40** was located beside the nozzle so that the yarn was snubbed across the exit face of the nozzle. The appearance of the treated yarn was as in FIGURE 8. The denier of the yarn was increased from 323 to 356. The effective volume of the yarn was increased to a much greater extent, resulting in a lofty, fuzzy yarn which has aesthetic merit, particularly for knitted fabrics. The changes in the yarn structure comprise a separation and reorientation of the fibers in relation to each other accompanied by intertangling to the extent that the reoriented fibers are stabilized in their new positions. The net result is a peripheral expansion of the central core of the yarn with an accompanying marked increase in the number and length of free fiber ends and the formation of crunodal loops and other convolutions characteristic of the process. Some properties of fabrics prepared from the untreated and the treated yarn were as follows:

Fabric Properties

	Before Bulking	After Bulking
Weight (oz./sq. yd.)	7.1	7.2
Thickness (cm.)	0.155	0.208
Specific volume (cc./gm.)	6.45	8.55

EXAMPLE 5

A variety of spun yarns were treated in a similar way with like results. The treated yarns were all taken up from the jet at 100 yards per minute, with other conditions as in Example 4 except as indicated in Table 1. In this table, yarn notations such as 50/2 (25 **Z**, 4 **S** ply) 5 in., 3 d.p.f. in 5(*e*) refer to a 50 cotton count, 2 ply yarn in which each of the plies has a **Z** twist of 25 turns per inch and the plies are twisted together in the opposite direction at 4 **S** turns per inch, the fibers being 5 inches long and of 3 denier per fiber. "Rayon" refers to regenerated cellulose yarn made by the viscose process. "Dacron" and "Orlon" are trademarks for yarn manufactured by E. I. du Pont de Nemours and Company and refer to polyethylene-terephthalate and polyacrylonitrile yarns, respectively. "Nylon" refers to polyhexamethyleneadipamide yarn. The appearance of the treated yarns was similar to that shown in FIGURE 8. However, it was observed that, as the staple length was increased, the amount of loop formation in the yarn bundle increased and, of course, the frequency of protruding ends decreased. The extent of the bulking action could be increased or decreased by varying the percent overfeed up or down from the values given in the table, but processing difficulties may be encountered at overfeeds above 15%.

Table I

PREFERRED PROCESS CONDITIONS FOR BULKING SPUN YARNS

Ex.	Yarn Treated	Overfeed, Percent	Air Pressure, lbs./sq. in.
5(*a*)	18/1 (14 Z) 8–10 in., 3 d.p.f. Rayon	18	50–70
5(*b*)	30/1 (19Z) 3.5 in., 3 d.p.f. Rayon	5	40–60
5(*c*)	40/1 (22 Z) 6–8 in., 3 d.p.f. Rayon	10	60–80
5(*d*)	10/1 (11Z) 5 in., 3 d.p.f. "Dacron"	6	60–80
5(*e*)	50/2 (25 Z, 4S ply) 5 in., 3 d.p.f. "Orlon."	6	60–80
5(*f*)	18/1 (15Z) 4–6 in., 2.5 d.p.f. Nylon	6	60–80
5(*g*)	15/1 (14 Z) 4 in., 3 d.p.f. blend of 50% "Dacron," 50% Rayon fibers.	5	50–70

EXAMPLE 6

A 20/1 worsted count (408 total denier) 9 **Z** twist spun yarn composed of 5 inch, 3 denier, acrylonitrile fibers was processed with the apparatus shown in FIGURE 1 at a speed of 15.5 yards per minute. Air was supplied to the nozzle at a pressure of 90 pounds per square inch gage, the air consumption being 2.44 cubic feet of free air per minute. The treated yarn was characterized by the protrusion of long ends of fibers from

the core of the yarn. These ends projected up to one inch, giving an extremely fuzzy, cashmere-like yarn. In other respects the yarn was similar to that shown in FIGURE 8.

EXAMPLE 7

A two ply, 27 cotton count, spun polyethyleneterephthalate yarn was processed at 15 yards per minute with apparatus similar to that in FIGURE 1. The plies of this yarn were composed of 1¾ inch staple length, 3 denier fibers twisted together at 18 Z turns per inch, and the ply twist was 11 S. Air was supplied to the nozzle at 90 pounds per square inch gage, the flow being about 1 cubic foot of free air per minute. The yarn bulked equally well both with and without the baffle plate. The appearance of the yarn is shown in FIGURE 9 and, except for the two-ply structure, was similar to the yarns described previously in connection with FIGURE 8. In this case the fiber and ply twists were sufficient to prevent the false untwist imparted by the jet from untwisting the yarn fibers for an undesirable distance, and snubbing against a surface was not necessary.

An attempt was made to process a single ply, 27 cotton count, 18 Z twist yarn composed of 1¾ inch, 3 denier polyethyleneterephthalate fibers under identical conditions. Without the baffle plate, or other means for snubbing the yarn close to the nozzle exit, the process could not be operated because the air stream pulled the yarn to pieces.

EXAMPLE 8

The previous examples have shown that the jet stream has sufficient false untwisting action to open up a wide variety of twisted yarns to the extent required by the process of this invention. However, it is sometimes desirable to accentuate the untwisting action by providing a rotating or torque jet stream. This has been accomplished by cutting oblique or spiralling grooves in the cone-shaped end 32 of the yarn guiding portion of the nozzle in FIGURE 1. For the purposes of the present example, however, the simple torque nozzle shown in FIGURES 2 and 3 was used with apparatus similar to that of FIGURE 1 to process single ply, 18 cotton count, 18 Z twist, spun yarn composed of 3 inch, 3 denier polyacrylonitrile fibers. Air was supplied at 90 pounds per square inch gage to give a flow at near sonic velocity of ½ cubic foot of free air per minute.

Using a nozzle having a 1/16-inch yarn passage and arranged to apply an S torque to yarn being treated, with the yarn snubbed ¼ inch from the nozzle exit at a distance of 1 inch from the air inlet and then taken up at 15 yards per minute, the Z twist yarn processed excellently to give a multitude of ring-like loops and fuzzy ends. The yarn processed better than the same yarn did in the straight-line jet stream of Example 3, even though the air consumption was only one-half as great. This nozzle appeared as in FIGURE 3 when looking upstream at the nozzle exit. The air inlet 54 was off center to the left, giving the air stream a clockwise rotation as it came toward the observer.

An attempt was made to use a nozzle with the air inlet off center to the right, which gave a counterclockwise rotation to the air stream and applied a Z torque to the yarn, but this had no appreciable effect on the yarn. This Z torque jet increased the Z twist of the yarn and prevented the opening action necessary for the type of bulking action described.

Cotton yarn also processed excellently under the above conditions with the S torque jet. Good results were obtained with a single ply, 18 Z twist cotton yarn having an average fiber length of 15/16 inches. Due to the short fiber length the bulking effect was somewhat less than for the above 3-inch fiber length polyacrylonitrile yarn. When an attempt was made to treat the cotton yarn with the snubbing point over 1 inch from the nozzle, under otherwise identical conditions, the process was not operable because the yarn pulled apart.

EXAMPLE 9

In Example 8 it was observed that the use of a Z torque jet nozzle increased the twist of Z twist yarn and prevented opening of the yarn, so that bulking did not take place. However, this type of treatment can be combined with heat-setting of the yarn while in the overtwisted condition to provide a crimp bulking effect. A single ply, 18 cotton count, 15 Z twist spun yarn composed of 4–6 inch, 2.5 denier, polyhexamethyleneadipamide fibers may be processed as in Example 8, using a torque nozzle which applies a false twist of about 30 turns per inch. The nozzle may be heated to about 240–250° C. to crimp set the yarn while in the false twisted condition. This produces a bulky wool-like yarn having an attractive curly crimp which imparts elasticity to the yarn. The fibers will retain their crimp when separated from the yarn.

It will often be more convenient to heat the false twisted yarn outside of the nozzle instead of heating the torque nozzle. The yarn guide 18 was spaced at a greater distance from the nozzle than shown in FIGURE 1 and a heating surface at 240–250° C. was used to crimp set the yarn between the guide and the nozzle. The yarn was passed through the torque nozzle without snubbing so that the false twist of about 30 turns per inch backed up to the yarn guide. With other conditions as described above, a similar crimp bulking effect was obtained.

The process of Example 9 is useful with any yarn composed of fibers which can be heat set to stabilize the crimp imparted by the false twist. The treatment is enhanced by fibers which shrink during heat-setting. While the process has been illustrated with spun staple yarn, it is equally applicable to continuous filament yarns, both twisted and untwisted. The process can be combined with the treatments of any of the other examples by adding another nozzle to apply a separate false untwisting and bulking step.

For example the yarns may be composed of a blend of high and low shrinkage fiber components. This mixed shrinkage yarn may be textured through the jet as described above and then shrunk by heating the yarn while in a relaxed state, e.g. in skein form. Alternatively, the yarn may be woven or knitted into a fabric and then heat relaxed during dyeing and finishing in fabric or garment form.

EXAMPLE 10

A nylon yarn (80/68/0) was fed to a jet similar to FIGURE 8 of U.S. 2,783,609 at 240 y.p.m. The jet was mounted so as to exhaust in an enclosure partly filled with cotton linters of about 1/16" in length (FIGURES 13 and 14). The pinch rolls as illustrated in FIGURE 14 were operated at 200 y.p.m. to give an intermediate overfeed of 20%. The wind-up was operated at 230 y.p.m. to give a net overfeed of 5% and a final denier of 91. Since the calculated denier under these conditions should be 84, the linters increased the yarn weight by about 8%. The yarn sample between the flocking box and the pinch rolls had an appearance illustrated in FIGURE 15. The final yarn showed reduced loop size as shown in FIGURE 16. Many characteristic random nodes and tangles could be observed under magnification. The short length staple fibers were firmly locked within a continuous filament knot or knot snarl or tangle of random configuration and frequently compound in structure; that is, more than one continuous filament and more than one staple fiber involved in a given snarl or tangle. Longer fibers may be used in place of those used to illustrate the invention in this example. In general the flock or linters may vary in length from about 0.1 millimeter, as is usually found in wood flour, up to lengths normally employed for staple fibers; that is, about 15 millimeters, although for many purposes staple up to about 5" may be used. In general

the shorter length fibers are loosely bound and have a tendency to be lost in yarn and fabric processing. Fibers of normal staple length in the range of 1" to 3" are entangled less readily by the bulked yarn and therefore tend to modify the yarn to a lesser extent in terms of the number of free ends. Longer fibers, however, have the advantage of being more permanent in the final fabric.

Any process which tends to entangle the longer fibers in the bulked continuous filament yarn may be used to advantage where the staple is long, for example, it may be desirable to pass the bulked yarn through a loosely compacted bat of randomly arranged fibers. The length of contact and compressional load on the yarn being treated should be balanced to avoid undue yarn tension tending to cause breakdowns but may be sufficient to cause filament loops to become locked about the entangled staple fibers and to deform large loops into the flattened configuration shown in FIGURE 17. Protruding fibers and elongated loops may be held temporarily in place by a size to improve weaving performance and reduce snagging characteristics in the final fabric.

Where improved yarn stability is the major goal, short length fibers such as Solka-Floc [1] wood cellulose may be employed with good results. The very short length fibers tend to be fugitive to some extent but increase stability of borderline yarns sufficiently to permit improved warping, quilling and weaving or knitting. The bulk of the finished fabrics may be enhanced even after loss of the short fibers due to the unoccupied spaces they leave behind.

Similarly, the bulked yarn may be passed through a liquid fiber slurry. With well dispersed fibrous material of suitable length and concentration the yarn emerges with much the appearance of a pipe cleaner and increased weight of up to 50% or more. Tension applied to this yarn may again be used to lock most of these fibers in place. Heavily loaded yarns tend, however, to lose a portion of the loosely attached fibers which may be blown, rubbed or shaken off and returned to the slurry.

The following experiments illustrate embodiments of the invention in which two different yarns are used, one of which is relatively shatterable and the other is relatively unshatterable.

32/2 worsted count with an 8 Z singles and a 4 S ply twist composed of a blend of 80% 2 d.p.f. relaxed and 20% d.p.f. high shrinkage fibers. This yarn was passed vertically through a nordinary glass T tube of ¼" diameter. Air under a pressure of 10 p.s.i.g. was directed through the horizontal leg of the T tube to deflect the yarn from its vertical path. The yarn was passed through the tube at about 60 y.p.m. A fuzzy yarn having a soft, bulky texture was obtained. The air pressure in the tube may be varied from about 10 p.s.i.g. to about 100 p.s.i.g. It is difficult to determine the velocity of the air in the tube, but when the air is under pressure in the higher range, its speed as it contacts the yarn is of the order of sonic velocity. The yarn processed in this manner has fewer loops and whorls and normally very few broken ends as compared with the products of the examples in which a high speed jet is used in conjunction with yarns containing a brittle component. The free ends project much further from the yarn bundle after treatment than they do in the starting yarn.

While the examples illustrate the use of acetate fibers as the brittle or shatterable component, it is to be understood that filaments of other materials may be substituted more or less directly in the examples. The suitability of a given filament for the purpose depends on its tendency to break under the high speed jet action. It has been found that this tendency may be determined by a flex resistance test which consists essentially of bending the filament repeatedly through 180° over a smooth wire under a specified tension. The number of cycles required to cause failure of the specimen is taken as a measure of its flex resistance. The test is carried out by conditioning filaments for at least 16 hours in an atmosphere of 70° F. at 65% relative humidity. Usually 21 filaments are tested together and the number of cycles required to cause failure of 11 filaments is accepted as the test result. The tension applied to the specimen may be 0.15, 0.3, or 0.6 gram per denier depending upon the brittleness of the sample. It is desirable to select a load

Table II

Example No.	A Core Ply	B Fractionable Ply	C Texturing Type Jet, p.s.i.	D Torque Jet, p.s.i.	E Windup Speed, y.p.m.	F Overfeed, Percent	Remarks: Process	Remarks: Product
11	"Dacron" 40/27/0	Acetate 55/36/0	[a] 90	90	204	5	Fig. 10	Many ends—fewer loops than Fig. 18.
12	Nylon 40/13/1/22	Acetate 55/36/0	90	90	204	9	Fig. 10	Fig. 18.
13	Nylon 20/7/1/22	Acetate 45/24/0	[a] 100	80	400	3	Fig. 11	Fewer free ends than Fig. 18.
14	Nylon 20/7/1/22	Acetate 30/20/0	[a] 100	80	409	3	Fig. 12	Similar to Ex. 13.
15	Green Acetate [d] 150/40/0.	Acetate 55/36	[a] 100	[b] 80	410	4	Fig. 12	Similar to Ex. 13.
16	Green Acetate [d] 55/36.	Green Acetate [c] 75/50.	[a] 100	80	201	3	Fig. 12	
17	"Dacron" 40/27/0	Acetate 45/24/0	[a] 100	100	201	4	Fig. 11, Steam used in torque jet.	Free ends wrap more completely and protrude less from main yarn bundle.

[a] Fig. 8, U.S. 2,783,609.
[b] Torque-jet located at alternate position Fig. 12.
[c] Acetate fibers with Y cross-section.
[d] "Green" implies yarn fresh from spinning unit having 5–20% residual solvent. This yarn is generally much tougher than "conditioned" yarn which has been allowed to lose acetone by prolonged storage in fresh air.

EXAMPLE 18

A stretched broken "Orlon" tow was processed to a

[1] Product of the Brown Co., 150 Causeway St., Boston 14, Mass.

factor which will result in a test lasting a minimum of 50 cycles and a maximum of 5,000 cycles. The 0.6 gram per denier load factor is satisfactory for most textile fibers. The order of magnitude of the flex life of com-

monly used fiber types under a 0.6 g.p.d. load are as follows:

Fiber:	Flex life
Nylon and "Dacron"	1,000,000
Rayon	3,000
Acetate	300
Polystyrene	10
Glass	1

In general, with other factors held constant, the tougher fibers may be stabilized by use of lower operating speed on the jet so that the individual increments of fiber length are exposed to the flexing action of the jet for a greater length of time, or by use of higher air pressure in the jet which gives a more violent flexing action in the jet. An example of the former deals with rayon which was processed at 20 y.p.m. to give a product similar to that obtained with acetate at 200 y.p.m. (roughly in inverse proportion to the tabulated flex lives).

Within a given fiber composition, a great range of flex lives may be obtained by changes in orientation and/or crystallinity. Normally, nylon and "Dacron" are much too tough to be fractured by the action of a texturing jet. If, however, they are prepared in a state of low orientation and high crystallinity the flex lives may be reduced to the range of a few hundred to a few thousand cycles. Molecular weight as indicated by relative viscosity in a suitable solvent also plays an important part in determining fiber toughness. "Dacron" fibers prepared from polymer with a relative viscosity of about 12 even though oriented and crystallized by normal process steps show flex lives in this same low range (100–10,000). Usually a filament having a flex life below about 10,000 may be substituted for the acetate in the examples.

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.

This application is a continuation-in-part of my copending application Serial No. 679,891, filed August 23, 1957, now Patent No. 2,869,967.

I claim:

1. A process for making a bulky yarn having a covering of projecting filament ends which comprises feeding a twisted yarn to a high velocity fluid jet and restraining the yarn from losing any substantial amount of its twist until the jet is reached, applying a false untwist to the yarn by means of the jet, jetting the fluid at a near sonic velocity to convolute yarn filaments and provide a multitude of projecting filament ends, withdrawing the yarn from the jet after a travel through the jet of less than the shortest filament length, and retwisting the yarn adjacent to the jet to hold the filament convolutions and filament ends in place.

2. The process of treating a textile yarn containing filaments which comprises forming a covering of convolutions and projecting filament ends about the yarn by subjecting it to a high velocity jet of air.

3. The process of claim 2 in which the yarn is given a false untwist by the jet of air.

4. The process of claim 2 in which the jet of air shatters some of the filaments.

5. The process of claim 4 in which the flex life of one component of the yarn is less than about 10,000.

6. The process of claim 4 in which the flex life of one component of the yarn is less than about 300.

7. The process of claim 2 in which the yarn contains staple fibers and the jet of air projects staple fibers.

8. The process of claim 2 in which the yarn contains staple fibers and is snubbed against a fixed surface adjacent to the point of entry into the jet of air and is snubbed against a second fixed surface at the point of leaving the jet of air, the distance between the two snubbing points being less than the average length of the staple fibers.

9. The process of claim 2 in which two independent plies are fed together and blended into a yarn in the jet of air, at least one ply being composed of staple length fibers twisted together.

10. A process for making bulky yarn having a covering of projecting fiber ends which comprises feeding to a high velocity jet a yarn composed of a plurality of plies of staple-length fiber, the fibers of each ply being twisted together in the same direction and the plies being twisted together in the opposite direction, applying a false untwist to the yarn by means of the jet, jetting the fluid at a near sonic velocity to convolute the fibers and to provide a multitude of projecting fiber ends and crunodal loops, withdrawing the yarn from the jet after a travel through the jet of less than the fiber length, and winding up the treated yarn, said twists of the fibers and plies being sufficient to prevent the false untwisting action of the jet from untwisting the yarn fibers for a distance of over one-half the length of the fibers.

11. The process of preparing a bulky yarn having a covering of projecting filament ends which comprises feeding a yarn to a high velocity air jet to form whorls and loops in the said yarn, passing the yarn while in this condition in contact with loose fibers and subsequently winding the yarn under tension.

12. The process of claim 14 in which the fibers are flock of from about 0.1 to 13 millimeters in length.

13. The process of claim 11 in which the fibers are in the form of staple up to about 5" in length.

14. The process of claim 11 in which the increase in the weight of the yarn due to the fiber pick-up is up to 50%.

15. The process of claim 2 in which the yarn is composed of a plurality of plies of staple-length fiber, wherein the singles twist is in one direction and the ply twist is in the opposite direction.

16. The process of claim 1 in which the twisted yarn is made up of a plurality of fiber elements, one of which has a high potential shrinkage and another has a low potential shrinkage, and thereafter shrinking the yarn by heating it while it is in a relaxed condition.

17. The process for making a bulky yarn having a covering for projecting filament ends which comprises feeding a yarn containing filaments to a high velocity gaseous jet, jetting the gas at near sonic velocity to convolute the yarn filaments and provide a multitude of projecting filament ends, withdrawing the yarn from the jet after a travel through the jet of less than the shortest filament length and thereafter winding the yarn on a package.

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