United States Patent [19]

Seem et al.

[11] **3,785,135**

[45] **Jan. 15, 1974**

[54] **PRODUCING TORQUE CONTROLLED VOLUMINOUS SET YARNS**

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[73] Assignee: **Leesona Corporation**, Warwick, R.I.

[22] Filed: **Apr. 5, 1971**

[21] Appl. No.: **131,367**

[52] **U.S. Cl.** .... **57/34 HS**, 57/34 B, 57/77.3, 57/140 R, 57/157 TS, 57/157 F

[51] **Int. Cl.** **D02g 1/02**, D02g 1/16

[58] **Field of Search** .... 57/140 R, 34 R, 34 HS, 57/34 B, 157 R, 157 F, 157 TS, 157 MS, 77.3; 28/1.4, 72.12

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Primary Examiner—Werner H. Schroeder
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[57] **ABSTRACT**

Disclosed is a method and apparatus for producing a torque-controlled voluminous set yarn. Novel false twisting means hereinafter referred to as a "whirler" is employed to impart a relatively low number of twists per inch to a torque stretch yarn by blowing air circumferentially around the yarn at a pressure and flow coordinated with the yarn tension and the amount of heat imparted to the yarn. The covering power of the yarn and the bulk or voluminosity of the yarn thus produced is enhanced and residual torque in the yarn is controlled uniformly throughout the length of the yarn which is treated. Also disclosed is a set yarn with high bulk and controlled torque characteristics, novel yarn packages, fabric produced therefrom and garments made from said fabric.

35 Claims, 14 Drawing Figures

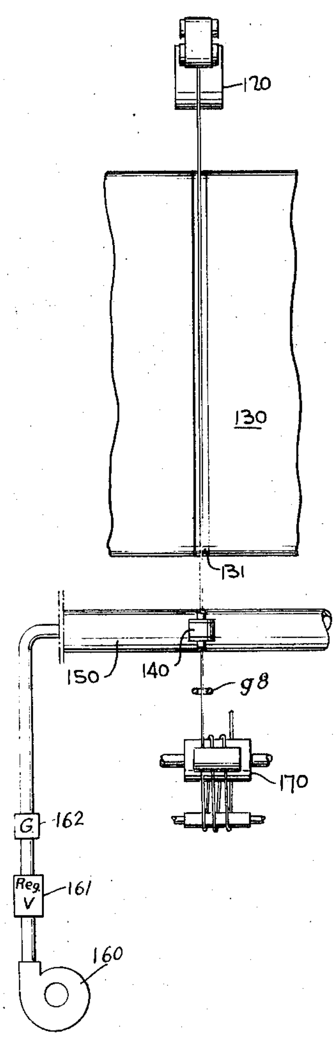
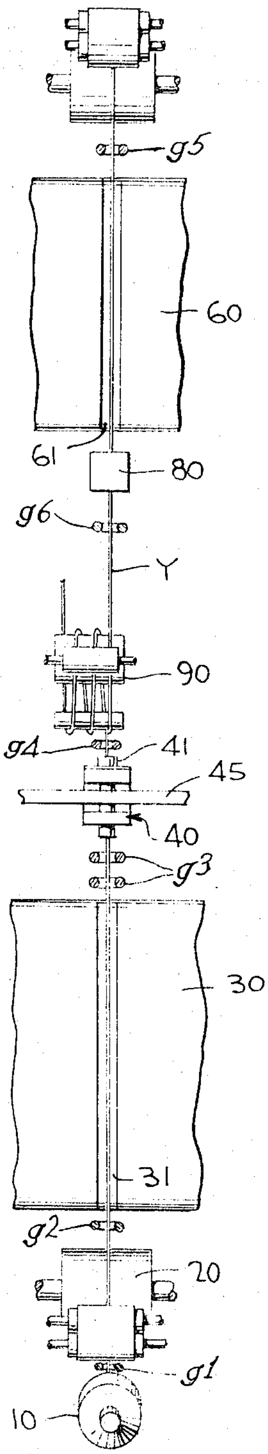


FIG. 1


g5
60
61
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Y
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45
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31
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20
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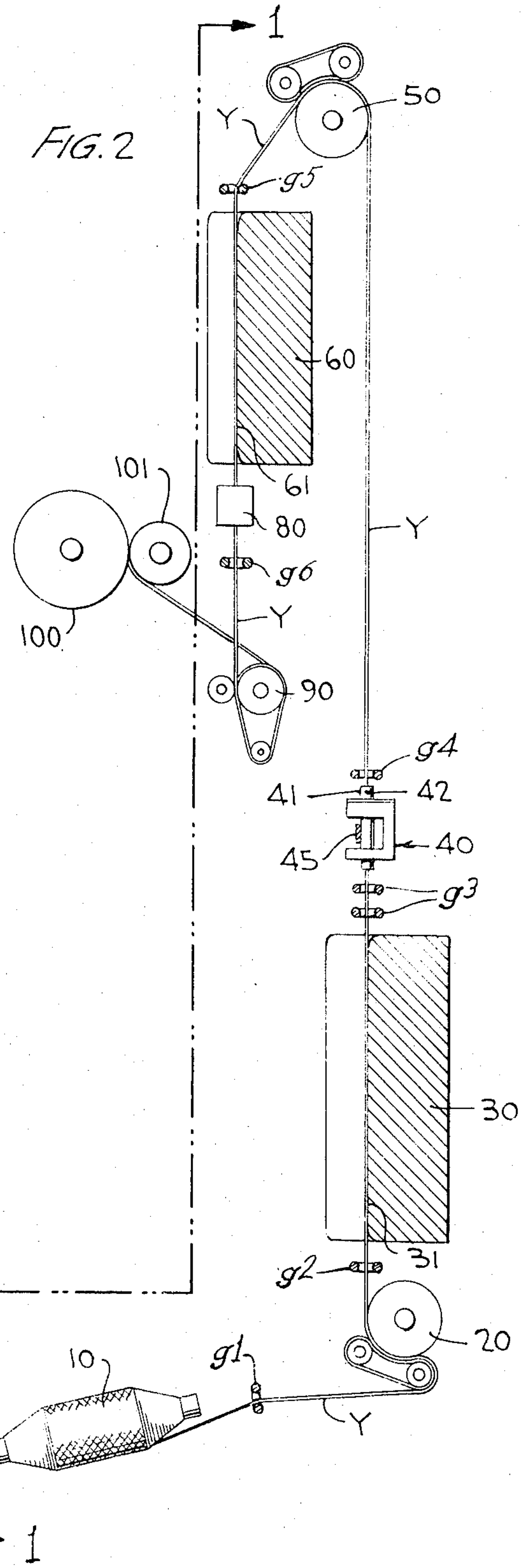
10

FIG. 2


1
50
Y
g5
60
101
61
80
Y
g6
100
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41
42
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30
31
g2
20
10
g1
Y
1

FIG. 3

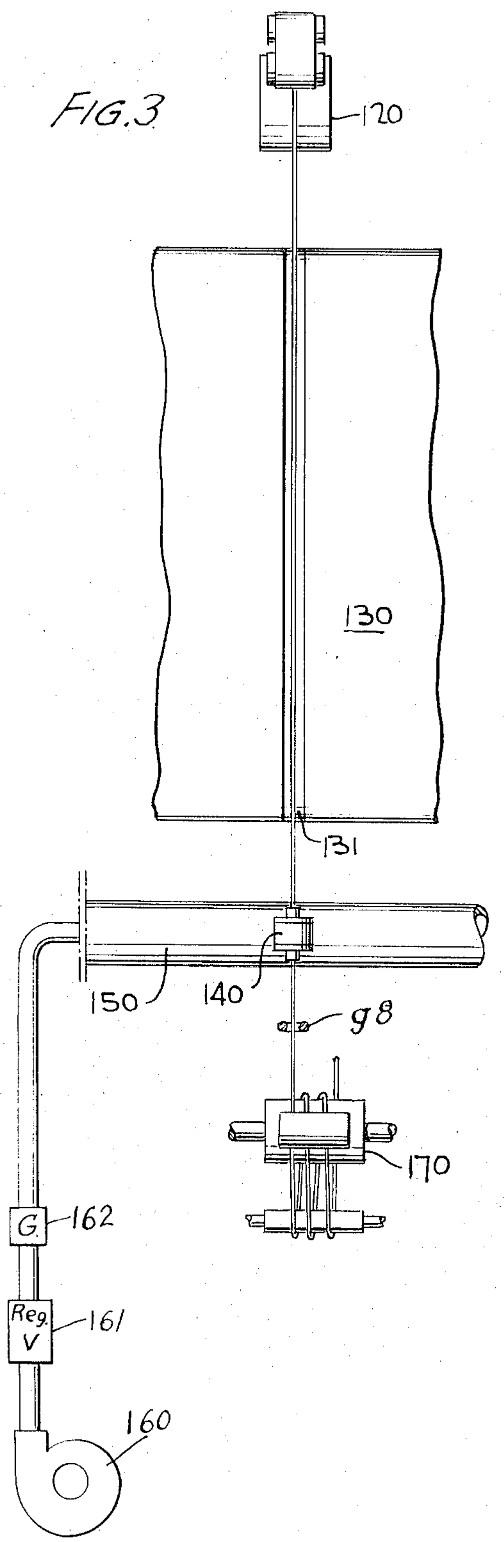

FIG. 4

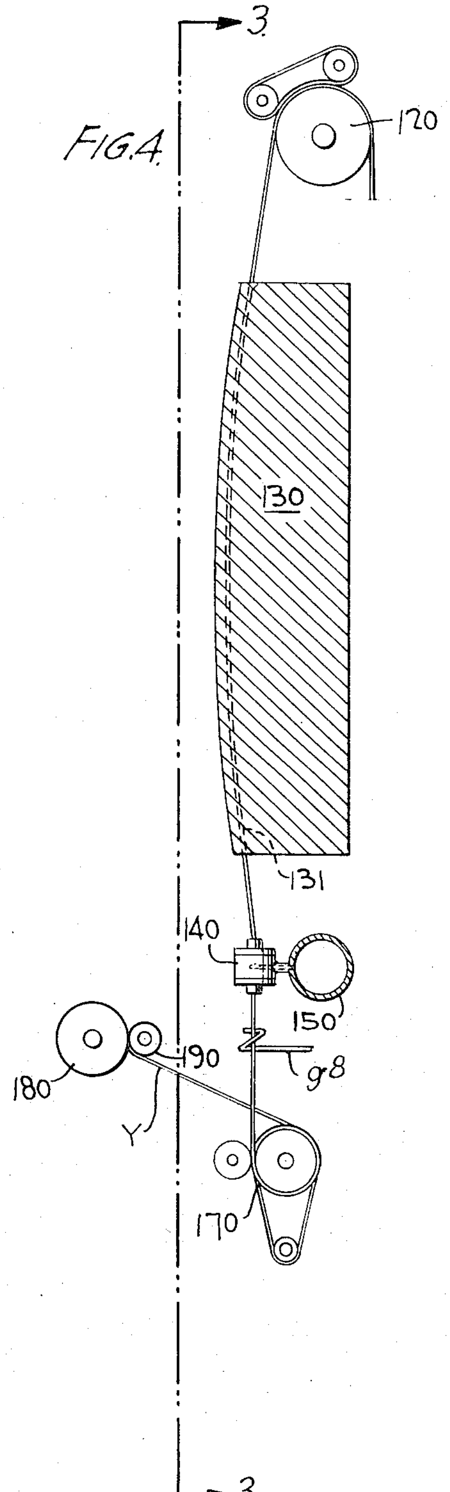

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FIG. 5.

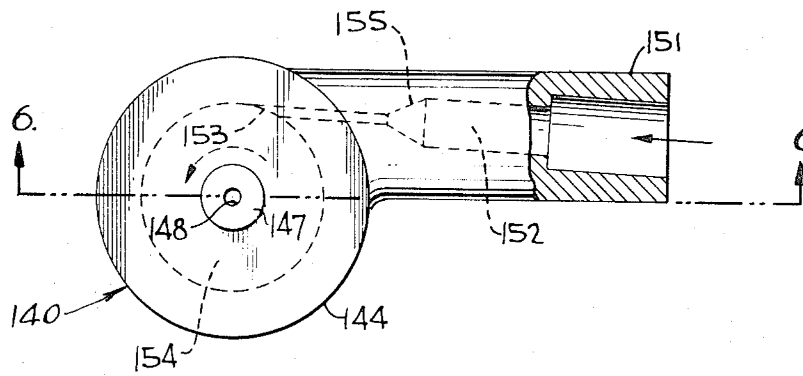
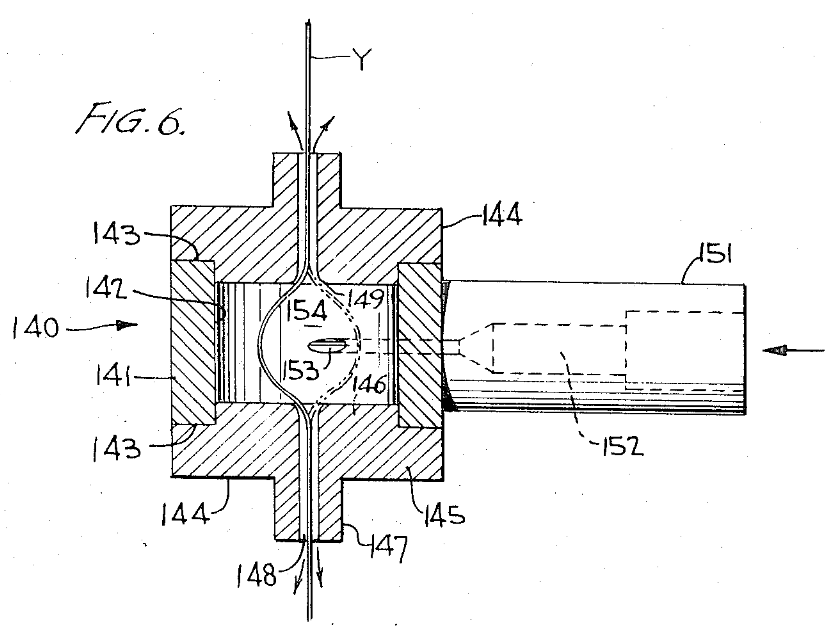


FIG. 6.



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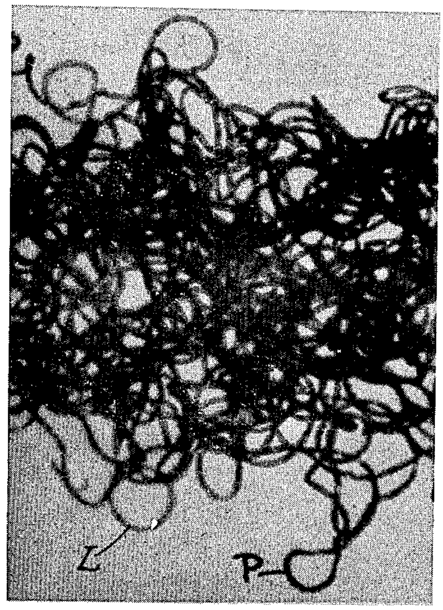

FIG. 7

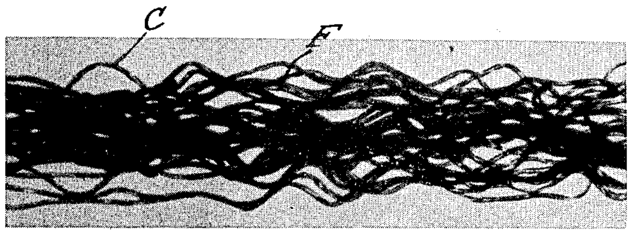

FIG. 8

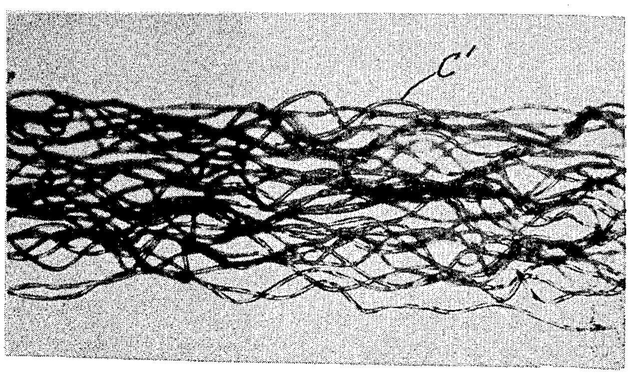

FIG. 9

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FIG.10

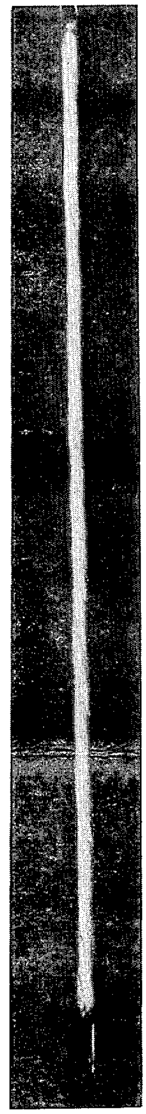

FIG.11

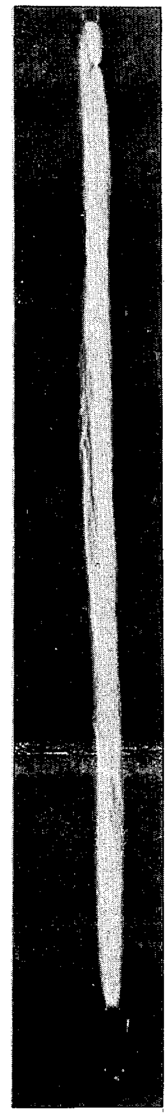

FIG.12

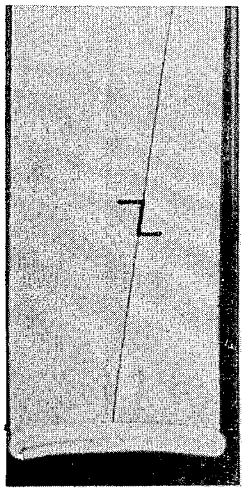

FIG.13

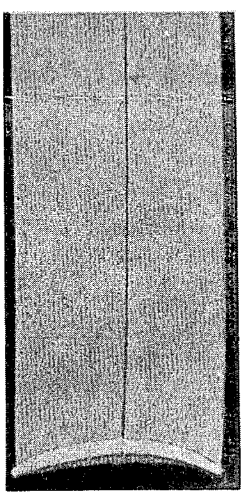

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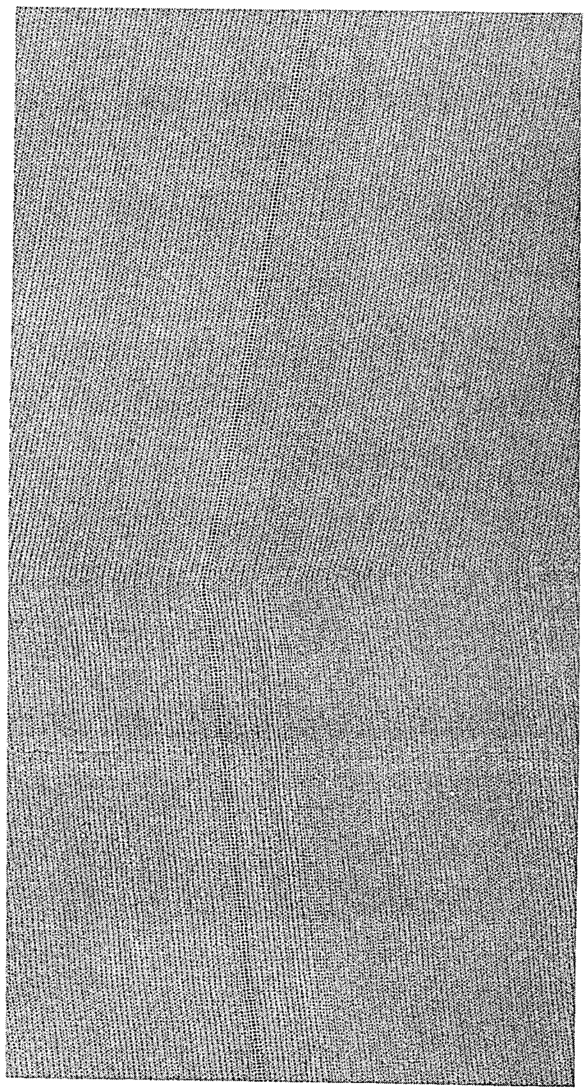
FIG. 14



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PRODUCING TORQUE CONTROLLED VOLUMINOUS SET YARNS

BACKGROUND OF THE INVENTION

The present invention relates to a process and apparatus for controlling torque and/or increasing bulk in a set yarn produced in a continuous or discontinuous process.

Much attention has been given by the textile art to so-called textured synthetic yarns. One such textured synthetic yarn is commonly referred to as a "torque stretch yarn." As is well known, torque stretch yarns have been treated to assume a crimped and pigtailed configuration so that they have stretch characteristics that distinguish them from untreated yarns.

A common tecnique employed in the production of torque stretch yarn, and one that is being practiced on a widespread scale, is known as "false twist texturing." This procedure involves twisting the yarn about its own axis, heating and then cooling the twisted yarn (commonly called "heat setting" the twist) and untwisting the yarn in a continuous operation under correlated tension without interruption between the individual steps.

"Torque stretch yarn," when examined on a filament-by-filament basis and free of tension is characterized by two separate types of deformations. The first of these deformations is commonly referred to as "crimp" and the second deformation is commonly referred to as "pigtails."

If a single filament of torque stretch yarn is grasped at both ends and allowed to relax substantially, the deformation known as "pigtails" is by far the most visible. The yarn filament will coil upon itself at frequent, random locations along the filament creating the "pigtails." If this same piece of yarn is elongated to the point where the pigtails have just uncoiled, the deformation known as crimp becomes more visible. The yarn now has a wavy appearance but is not pigtailed or coiled upon itself. It is to be understood that the crimp is present in the filament pigtails, but because the pigtail deformation is larger than crimp deformation, most of the crimp is visually obscured by the pigtails until the pigtails are stretched out of the filament. If this same filament is elongated still further, the crimp will disappear and a straight filament is the ultimate result. Upon relaxation, however, the crimp and ultimately the pigtailing will reappear.

Commercial false twist yarn is uniformly twisted, heat set and untwisted. However, when the yarn is caused to relax it does not do so uniformly. This is due to the position of the filaments in the yarn bundle while heat set, as well as the position the filaments assume after untwisting, partly resulting from inter-fiber friction and filament phasing. Some stresses in the filaments tend to work in unison while others tend to oppose one another. Stresses are therefore non-uniformly relieved when untwisted. When such forces combine, the result is voids or sections of yarn with small cross-section; where the opposite occurs, and the forces in the filaments oppose one another, the cross section is increased and more bulk is realized.

The textile art has shown great interest in what has come to be known as "set" yarn. A set yarn, briefly described, is created when a torque stretch yarn is relaxed from its fully stretched (straightened) configuration to the point where the crimped configuration is present in

the yarn but the pigtails caused by torque are not permitted to form and the yarn in this crimped configuration is then treated by heating and then cooling so that a substantial amount of torque is permanently removed from the yarn but the crimp is substantially retained. Set yarn is of commercial importance because of its bulkiness, voluminosity or covering power. Bulk may be defined as the covering power of the yarn per unit weight.

At the present time, a known method for producing set yarn includes the overfeeding of a torque stretch yarn into a yarn package to produce what is known as a "soft package" and then subsequently autoclaving the soft package. The yarn is first straightened and the overfeed is then adjusted so that the yarn in the soft package has a shallow crimped configuration but no pigtails. A visible crimp configuration remains in the yarn after the application of heat, pressure and moisture in the autoclaving step but is only fully developed during fabric finishing. Tens of million of pounds of such yarn is produced annually. As is apparent, this is a discontinuous or batch method of producing set yarn. As in any batch process, there is inherently substantial variation within individual packages and from batch to batch, and such variations produce non-uniformity in set yarns produced in such manner,

A method for producing more uniform set yarn than obtained by the batch method is one in which the process is continuous. That is, torque stretch yarn is drawn directly from the false twist supply under sufficient tension so that it is straight and is overfed at a given value across a yarn heater. The overfeed across the heater is adjusted so that all or substantially all of the torque induced pigtails are removed but so that the crimp in the yarn is substantially retained. When the yarn is drawn over this heater under controlled conditions of temperature and tension the stresses which are non-uniformly relieved in the initial untwisting are caused to be made permanent thereby resulting in considerably less than the optimum potential uniformity of yarn and fabric appearance.

Several types of machines exist for performing the continuous method of producing set yarn. For example, "torque stretch yarn" may be produced on one machine that winds the torque stretch yarn into a package. The package is then conveyed or carried to a second, separate machine comprising a feed roll, a yarn heater, a cooling zone and a take-up mechanism. The "torque stretch yarn" is then overfed across the heater under a tension at which a crimped configuration exists, and while in this configuration the yarn is heated and cooled so that a crimped configuration is fixed into the yarn. Here again, considerably less than the optimum potential uniformity of yarn and fabric appearance is achieved.

Alternatively, set yarn may be produced on a machine that combines the operation that produces "torque stretch yarn" with the subsequent processing of this yarn into "set" yarn. A strand of yarn may be drawn from a package, false twisted in the region of a first yarn heater, cooled and untwisted under correlated tension to produce a "torque stretch yarn." This yarn is then drawn to a second heater by a set of feed rolls and is overfed across the second heater. The overfeed is controlled to provide a tension so that the configuration assumed by the "torque stretch yarn" is that of "set" yarn and a set yarn configuration is fixed into the yarn by the heating and cooling steps. This set yarn is then passed to a take-up mechanism and is wrapped into a package. Machines for performing this second-described process are Model 570 attachments to Model 553 or 555 false twist machines, all produced by Leesona Corporation, under U.S. Pat. Nos. 3,077,724 and 3,091,912.

A problem in the production of set yarns is that of residual torque. Torque is reduced during the annealing step in the subsequent or second heater treatment. However, residual torque remains in the yarn, which torque is readily detectable by any one of a number of simple tests. As an example of such a test, one may grasp a 1 foot length of yarn after the second heat treatment, tie a paper clip to one end of the length of yarn and, by holding the other end, allow the length of yarn to hang freely in a vertical position. The residual torque in the length of yarn will cause the paper clip to rotate a number of turns, as for example seven turns.

Another problem which is particularly apparent when using two-heater machines is that one is limited in choice of operating conditions (temperature, tension, etc.) which determines bulk and hand, by the need of also selecting conditions which produce a yarn having a level of residual torque such that it may be economically processed into fabric form at a subsequent time, even though this may entail warping in one case, knitting in another case, and weaving in still another case. If the prior machines are regulated to minimize residual torque, the production is impaired to an extent that it is no longer economical to utilize the yarn in the desired fabric form.

The present invention makes it possible to employ an increased range of operating conditions in the operation of two-heater machines and nevertheless to regulate residual torque in the yarn to the extent that it will not snarl or tangle when relaxed during the course of subsequent handling operations such as warping, knitting, weaving and the like, and may therefore be economically formed into fabric. The invention also makes it possible to incorporate set yarns into fabrics that heretofore could not be made in a commercial quantity or quality with the existing set yarns.

Although the aforesaid U.S. Pat. Nos. 3,077,724 and 3,091,912 disclose the elimination of residual torque by reprocessing the yarn through a false twist spindle, attempts to produce a set yarn without residual torque have not been universally successful. Because of the sensitivity of the torque stretch yarn to tension and heat, the previous attempts to process the yarn so as to eliminate the torque have accentuated the nonuniformity which is introduced by the false twisting operation. Furthermore the expense of running the yarn through an additional mechanical twister makes the cost of the yarn prohibitive. Treatment in accordance with the present invention provides a yarn which has been found to exhibit a greater degree of uniformity in characteristics throughout its length, and in certain instances has produced yarns having improved characteristics over the yarns not so treated.

The nonuniformity of the prior art set yarns is apparent in warp knitted fabric such as tricot knits in which the knitted structure is masked by the stitch configuration, but wherein the nonuniformity of the yarns composing the fabrics is accentuated by the manner in which the yarns are laid or knitted into the fabric. Since a major portion of the yarn appears on the face of the fabric in warpwise lines, differences in the characteristics of yarns in adjacent lines become readily apparent and appear as streaks in the fabric which detract from the quality of the finished product.

The elimination of residual torque which is made possible by the present invention has particular value with respect to certain yarns, as for example nylon, which generally are not presently processed on two-heater machines because the operating conditions which produce the desirable bulk and hand also leave undesirable residual torque in the yarn which makes it impractical to process such yarn economically into fabric. In particular, according to this invention, it is possible to produce set nylon yarns which have significant value in areas of use in which generally polyester yarns alone are now used.

Ideally, set yarn employed in a knitting operation should be substantially torque free. A convenient laboratory method for illustrating the effect that yarn torque has on fabric in the knitting of a test sleeve of fabric with a Single Jersey Knit. As discussed below in the description of the preferred embodiments of the invention, and particularly in connection with FIGS. **12 – 14,** Single Jersey Knit is a knit that clearly illustrates the effects of torque in the yarn. The angular orientation of the wales of the sleeve is a function of the amount of torque in the yarn. The angle created between the wale of the fabric and the longitudinal axis of the sleeve is known as the torque angle. The complement of this angle is the angle measured between the wales and the courses of the fabric. The torque angle is zero when there is no torque in the yarn and decreases with an increase in the torque in the yarn. It is desirable to minimize the torque angle when producing a commercial fabric.

SUMMARY OF THE INVENTION

According to the instant invention, an improved false twisting operation is provided to impart a relatively small number of twists per inch to torque stretch yarn as it is overfed under controlled conditions across a yarn heater. By imparting a small number of twists per inch in a direction opposite to that of the twist imparted during the "torque stretch yarn" producing process, the small number of twists will tend to counteract some or all of the residual torque that would normally remain in "set" yarn.

When treating yarn in accordance with the present invention, the number of twists per inch imparted to the yarn by the improved false twist means is of a substantially lesser number than the number of turns of twist imparted to the yarn during the initial production of the torque stretch yarn. The number of turns of twist imparted by the second false twist means should not exceed 25 percent of the number of turns of twist imparted by the first false twist means if optimum benefits are to be achieved. Thus, for example, if 48 turns of S twist are imparted to the yarn by the first false twist means, then less than 12 turns of Z twist should be imparted to the yarn by the second false twist means.

In the previous brief description of the production of set yarn, the elimination of the pigtail deformations was discussed. Heat alone will diminish the torque in the yarn yet substantially retain the crimp. The relatively small number of twists imparted to the low-tensioned yarn by the twisting operation according to the instant invention while subjected to the heat of the second heater, diminishes the yarn torque more than the torque is diminished by heat alone, yet retains the crimp in the yarn at substantially the level attained by heating alone.

The treatment by the present invention permits the individual filaments to assume a more uniform condition within the yarn bundle as they are subjected to the second successive twisting operation while heated, and untwisting operation when cooled, all while the yarn is substantially tensionless by having its feed rate correlated to the rate of advance to be substantially tensionless. The improved treatment is achieved by twisting the yarn in a direction opposite to that in which it tends to rotate with a low-pressure fluid, false-twisting means such as air which re-arranges the filaments within the yarn bundle and relieves the interfiber friction while rotating the bundle. The rearranged yarn upon leaving the heated zone is cooled and thus set before untwisting with a resulting improvement in yarn uniformity while at the same time controlling the torque forces in the bundle of filaments.

An improved false twist means which produces these unobvious and unexpected advantages is a pneumatic or similar fluid yarn twisting device which henceforth will be designated "whirler." This false twist means is constructed in a manner to create a fluid whirl within a confined cylindrical enclosure when fluid such as air is introduced therein and the whirling action twists the yarn about its own axis as the yarn passes longitudinally through the cylindrical enclosure, with the action of the air or the like, not only disengaging the multitude of filaments by a positive reverse twisting action but also by tending to blow the filaments apart, one from the other, with the direction of the flowing air or the like having a sufficient component tangential to the periphery of the bundle of filaments to cause positive rotation and at the same time having sufficient flow to aid in the filament separation. The air, or other appropriate fluid, enters the cylindrical enclosure tangential to the inner cylindrical surface and the direction or hand of twist imparted to the yarn and the degree of filament separation is a function of the orientation of the fluid inlet hole or aperture.

During operation, the twist imparted by the second false twist means travels upstream across a yarn heater. For ease in threading up, it is preferred to use a contact heater which produces a twist gradient in turns per inch in the yarn along the arcuate contact surface, the maximum twist being present in the yarn where it has the greatest degree of heat softening at the exit end of the heater, and minimum twist at the entrance end of the heater. In a radiant heater, the twist gradient through the heater is less pronounced, it being present as a result of different receptivity to twisting due to different degrees of heat softening. For purposes of subsequent discussion, this heater will be referred to as the second heater, inasmuch as it is often used on the same machine on which torque stretch yarn is produced by the action of a first false twist spindle that twists yarn in the region of a first heater.

The second heater has yarn advancing rolls capable of independent rotation that are located both upstream and downstream of the second heater. The torque stretch yarn arriving at the upstream roll is substantially straightened. By operating these rolls at controlled relative speeds and, more specifically, by operating the upstream roll at a faster speed than the downstream roll, it is possible to overfeed the yarn across the second heater in a substantially tensionless condition which permits treatment according to the present invention. With the usual heater temperatures and residence time, best results are obtained if the overfeed is in the range of 5 to 25 percent, since with an overfeed below a value of 5 percent, the contractile force in the yarn is such that little or no crimplike deformations are permitted to form in the yarn. With an overfeed above a value of 25 percent, the yarn tension is so low that pigtails form and it is difficult to twist the yarn with the second false twist means.

Continuing the discussion of operation, the yarn with twist imparted thereto by the second false twist means is heated by the second heater and then passes through a cooling zone between the second heater and the improved false twist means.

Under proper operating conditions, yarn so treated exists from the second false twist means with minimized residual torque and with substantial crimp level. The torque may be controlled within narrow limits to produce a substantially zero torque yarn that will knit or weave into a fabric that has improved hand and covering power and that has a small torque angle.

Of particular advantage is the simplified structure of the improved pneumatic false twist means. This false twist means has no moving parts and few wear surfaces and therefore present. In addition to long life and relatively maintenance-free operation, the air pressure required to efficiently twist the yarn is low enough to eliminate the need for costly compressors and the like. A fan or blower is sufficient to provide the pressure and quantity of air flow necessary to operate the device. Less than 10 pounds per square inch of air pressure is required for most commercially produced yarns. For special yarns as much as 30 pounds per square inch of air pressure may be used.

The bulk or voluminosity of the set yarn that is produced in accordance with the present invention is characterized by uniformity as well as greater covering power. It has an improved loft and the torque can be substantially equal to zero or reversed, so that the fabric made therefrom may have a torque angle equal to substantially zero, or even reversed.

The apparatus of the present invention permits treatment of yarn in a highly economical manner with minimum energy dissipation.

It is also an object of this invention to provide improved control of torque in set yarn while also enhancing the bulk of the yarn.

Other objects of the instant invention will be apparent to those skilled in the art upon consideration of the following specific description and claims, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic fragmentary elevation of apparatus employed to continuously produce and process set yarn as seen from the line 1—1 of FIG. 2;

FIG. 2 is a sectional view showing one station of apparatus employed to continuously produce and process set yarn;

FIG. 3 is an enlarged schematic fragmentary elevation of the apparatus employed to continuously treat torque stretch yarn to produce set yarn, as seen from the line 3—3 of FIG. 4;

FIG. 4 is a sectional view showing one station of an apparatus employed to continuously treat torque stretch yarn to produce set yarn in accordance with the present invention;

FIG. 5 is a top view of a pneumatic or similar fluid false twist device (whirler) embodied in the apparatus of FIG. 3;

FIG. 6 is a sectional side view of a pneumatic or similar fluid false twist device (whirler), taken on line 6—6 of FIG. 5 and showing the path of a strand of yarn as it passes through the device;

FIG. 7 is a photograph of a relaxed torque stretch yarn bundle prior to treatment in accordance with the present invention;

FIG. 8 is a photograph of a relaxed set yarn bundle of the prior art;

FIG. 9 is a photograph of relaxed reduced-torque set yarn bundle produced according to the instant invention;

FIG. 10 is a photograph of a test skein wound from set yarn of the prior art showing the twist which is produced by the residual torque;

FIG. 11 is a photograph of a test skein wound from reduced torque set yarn produced according to the instant invention;

FIG. 12 is a photograph of a test sleeve of fabric which was knit from set yarn of the prior art and has a torque angle other than zero;

FIG. 13 is a photograph of a test sleeve of fabric knit from reduced torque set yarn produced according to the instant invention. The sleeve illustrates a torque angle substantially equal to zero; and

FIG. 14 is a photograph of a test sleeve of fabric knit from a continuous length of yarn, the top part of which fabric was knit from set yarn of the prior art and the bottom part was knit from yarn made in accordance with the present invention where the torque was reversed.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

In this description the term "thermoplastic yarn" will be understood to embrace all textile strand-like materials, including staple and multifilament yarns that are thermoplastic by composition or that have been chemically treated so as to render them capable of being set in a functional deformed position while heating and cooling, as disclosed in U.S. Pat. No. 3,425,208.

The present invention will be described in combination with other elements of testile yarn processing machines that are used to produce conventional set yarn.

With particular reference to FIGS. **1** and **2**, unprocessed thermoplastic yarn Y is drawn from supply **10**, passed through guide g–1 and over the first set of feed rolls **20** and passed in contact with heated surface **31** of first heater **30.** Yarn Y is then passed through a twist-trapper **42** of a first false twist device **40,** in the present case a pin through the spindle blade **41** of a high-speed spindle driven by a belt **45,** and passed on to a second set of feed rolls **50.** Appropriate guide means *g*–**2**, *g*–**3** and *g*–**4** are located on both sides of the heater **30** and first false-twist device **40.** Yarn Y is then passed in contact with the heated surface **61** of the second heater **60** and through a second false twist device **80,** disposed between guide means *g*–**5** and *g*–**6,** is passed around a thrid set of feed rolls **90** and is collected on a take-up package **100** which is driven by a cork roll **101.**

It is apparent that the apparatus of FIGS. **1** and **2** is similar to the prior art two heater apparatus for processing "set yarn," except for the presence of the additional false twist device **80** therein. The yarn which passes upwardly from the supply package **10** through the heater **30** and false twister **40** is regulated as to speed and twist in the manner set forth in the previous patents referred to to incorporate torque stretch characteristics into the yarn Y, after it is cooled and untwisted by the first false twist device **40.**

In accordance with the present invention, yarn is fed through the improved false twist device of the present invention (indicated by the block at **80**) in a substantially tensionless condition by overfeeding the yarn. The yarn in this stage of the apparatus is controlled as to tension by the feed rolls **50** and **90** which may be considered the entrance and exit feed rolls respectively, for the setting zone which includes the heater **60** and false twist device **80.**

It should be noted that the position of the false twist device **80** must be selected so that it is in a straight line with the contact surface of the heater **60.** In this way, the twist generated by the false twist device **80** may travel into the heated yarn to effect a degree of molecular reorientation. The spacing between the heater **60** and the device **80** must be such that before the yarn is untwisted by the device, the yarn has had an opportunity to cool sufficiently to retain the set.

The speeds of rotation of feed rolls **50** and **90** are adjusted relative to each other so that the yarn is fed across the heater by roll **50** faster than the yarn is taken up by roll **90.** This relationship is known as an overfeed, and overfeed is generally expressed as a percentage of the exit speed, defined in the following manner.

$$\text{Percent overfeed} = \frac{[(\text{Yarn speed at feed roll 50}) - (\text{Yarn speed at feed roll 90})]}{(\text{Yarn speed at feed roll 90})} (100)$$

The overfeed is adjusted according to the characteristics of the previously processed yarn so that this yarn will relax and contract in the heated zone of the second heater to a degree sufficient to permit the crimp to develop but yet prevent the formation of torque-induced pigtails.

The direction of rotation of the second false twist means **80** is chosen so that if, for example, false twist spindle blade **41** is rotated in a direction to impart a given number of turns of S twist to yarn Y in the region of heater **30,** then according to the present invention, false twist means **80** is operated in a direction to impart a substantially lesser number of turns of Z twist to the yarn in the region of heater **60.**

It is noted that in the apparatus of FIGS. **1** and **2,** the yarn is set in a continuous operation following the incorporation of the torque stretch characteristics into the yarn in the first zone of the machine. It is noted that the heaters **30** and **60** in FIGS. **1** and **2** are provided with a substantially flat yarn-engaging surface **31** and **61** to minimize the drag imparted to the yarn in its travel over the heater surfaces. The flat surfaces are believed to reduce the twist gradient over the heater and permit full development of the twist as early in the travel of the yarn as practical. However, for many yarns, a flat heater does not provide the maximum heat transfer which is desired to insure proper heating of the yarn throughout its entire residence time in the heaters.

A preferred heater is shown in FIGS. 3 and 4 wherein the yarn-engaging surface of the heater is slightly arcuate to insure firm sliding engagement of the yarn upon the arcuate heater surface. FIGS. 3 and 4 illustrate an apparatus for setting torque stretch yarn in accordance with the invention. The apparatus in FIGS. 3 and 4 may be used independently of other equipment to treat torque stretch yarn which has been previously texturized on other apparatus, or the apparatus may be substituted for the feed rolls **50**, heaters **60**, false twister **80**, feed rolls **90** and takeup **100** of the composite machine shown in FIGS. **1** and **2**. It is noted that the apparatus of FIGS. 3 and 4 has entrance and exit feed rolls **120** and **170** respectively which are similar to the rolls **50** and **90**. The heater at **130** is a contact heater having an arcuate yarn engaging surface as indicated at **1** and is substantially elongated in order to provide the desired residence time for the yarn on the heater surface. It should be noted that the axis of the twister **140** is coplanar with the arcuate path of the yarn across the heater (a plane perpendicular to the drawings in FIG. 3), so that the twist imparted to the yarn by the twister is free to migrate back through the heating zone without retardation due to substantial bends or curves in the yarn path.

In accordance with the invention, the yarn traveling over the heater **130** is twisted by pneumatic forces in the improved false twisting device shown at **140** in FIGS. 3 and 4. The device **140** is supplied with pressure fluid from a manifold **150** which, in the present instance, is supplied with low pressure air from a suitable supply such as the blower **160** having a regulating valve **161** and a pressure gauge **162** associated therewith. A guide *g*–**8** is mounted downstream of the twisting device to guide the yarn onto the exit feed rolls **170** from which it is collected by a takeup package **180** rotated by a driving roll or cork roll **190**. It is understood that the illustrated apparatus in FIGS. 3 and 4 is a single station in a multiple-station machine, and the manifold **150** supplies low pressure air to each station. Although the drawings illustrate a single regulating control **161** for the manifold, it is apparent that the multiple-station machine may include several controls for insuring proper regulation of the air pressure for each pneumatic twisting device **140**.

With particular reference to FIGS. **5** and **6**, the whirler **140** is characterized by a tubular cylindrical mid-section **141** that has an interior surface **142** and end surfaces **143**. End plates **144** are composed of three integral cylindrical sections of different diameter. A cylindrical body section **145** has the same external diameter as the external diameter of the cylindrical mid-section **141**; a cylindrical insert section **146** has a diameter sized to be press fit in an airtight manner with the interior surface **142** of the mid-section **141** to form a whirl chamber **154**; and a small end tube or nose section **147** projects from the exterior side of the plate centrally thereon. A bore **148** for the passage of yarn through the device is drilled or otherwise formed through the longitudinal axis of each end plate **144** so that it passes through the geometric center of the surface **142**. The nose sections **147** at the upper and lower ends of the whirler provide sufficient length to the bore passageways **148** to insure substantially axial flow of the air discharging therethrough, avoiding disruptive cross currents which might cause entanglement of the yarn filaments. Furthermore the lengths of the passages **148** insure equal pressure drops top and bottom which assist in maintaining the desired circumferential air flow within the chamber.

The innermost portion **149** of the bores **148** flare slightly to break the sharp edge as the yarn contacts the plates **144** at this point while it is twisted by the fluid whirl. If desired, a ceramic or other wear resistant coating or insert may be placed at **149** to resist wear caused by contact with the yarn.

The manifold **150** (FIG. **4**) supplies air or other appropriate fluid to the whirler through a tubular circuit **151** (FIG. **6**) which is attached to or integrally formed with midsection **141**. The conduit **151** has a bore **152** formed therethrough that forms a fluid passage between the manifold **150** and the wirler **140** and terminates in a fluid inlet hole or aperture **153** (FIG. **6**) where the bore intersects the inner cylindrical surface **142** of mid-section **141**.

The axis of the bore **152** is tangential to the interior surface **142** of the cylindrical mid-section so that air is introduced into chamber **154** in a manner to produce a whirl that twists the yarn in the direction shown by the arrow in FIG. **5**.

During actual operation, a yarn balloon, such as the one shown in FIG. **6**, may be formed by the whirling action of the air of similar fluid. Since the fluid exits from chamber **154** through both of bores **148** formed in the end plates **144**, the planar interior surface of both end plates **144** and the elongated bore passages **148** cooperate to substantially reduce the venturi effect which would necessitate an uneconomical increase in the total air flow through the whirler, and disturb the gentle air action upon the yarn filaments.

The inlet bore **152** in conduit **151** may be of constant diameter or may be formed with a necked-down portion **155**. With the latter, a nozzle effect is achieved that accelerates the flow of air as it enters along the cylindrical wall **142** of the whirl chamber **154**. The inlet port **153** is positioned substantially tangential to achieve maximum efficiency in the formation of a whirling action.

Not only is the bore **152** disposed tangential to the cylindrical surface **142** in a plane perpendicular to the axis of the surface, but also the axis of the bore is parallel to the end walls **143** and the interior exposed surfaces of the end plates **144**. The axis of the bore **152** is positioned midway between the end plates so that the whirler is symmetrical about the transverse center line of the device.

The symmetrical form of the whirler not only enables the identical whirler to be used to insert both Z twist and S twist by selectively inverting the whirler, but also insures uniformity in treatment since the air is introduced along the center line and the pressure of the air which accumulates in the chamber causes the air to discharge equally through the top and bottom bores **148**. This equal flow of air upwardly and downwardly along the yarn axis effectively counterbalances any frictional drag imparted to the yarn by the axial air flow in the bores **148**.

The pneumatic whirler of the present invention effects a gentle opening action upon the yarn filaments during the twisting operation which insures separation of the filaments and avoids non-uniformity due to bunching and the like.

The whirler is economically manufactured since it is devoid of moving parts and requires no mechanical drive. The simplicity of the construction enables polishing of the surfaces to avoid any rough edges that might snag the yarn and is fully effective in operation and use.

In order to reduce or eliminate residual torque in set yarn, in operation the whirler is positioned so that the whirl created by the fluid imparts a twist in a direction opposite to the twist imparted in the torque stretch yarn producing process; the turns of twist imparted by the whirler is controlled; and the overfeed of the yarn is regulated to provide the desired substantially tensionless condition in the whirler chamber, commensurate with the ability to effect axial travel of the yarn through the chamber without snarling.

Because of the nature of the whirling action of the pneumatic or similar fluid false twist means (whirler), it is difficult to precisely measure the number of turns per inch that may be imparted to the yarn as it is being twisted by the whirler. For mechanical twisting means, such as a false twist spindle, it is only necessary to know the linear speed of the yarn as it passes through the spindle and the revolutions per minute of the spindle to calculate the number of twists per inch. Such a calculation for the whirler cannot be made on the same basis because the yarn is being twisted by a whirl of air rather than a spindle rotating at a known speed.

It has been empirically determined, however, that the number of whirler twists per inch necessary to practice the present invention are substantially less than the number of twists per inch imparted to the yarn during the torque stretch yarn producing process and less than 25 percent of the twist per inch imparted by the first false twist device. The empirical determination is made by comparing the pneumatically twisted yarn with mechanically twisted yarn processed with a mechanical device under known conditions of operation.

It has been found, however, that the number of twists imparted by the whirler is a function of the yarn denier, the yarn tension, the air or fluid pressure, and the inlet aperture size. For a given yarn, the twist is altered by changing the air pressure in the whirler.

The amount of overfeed which is imparted to the yarn by the rolls **50** and **90** in the apparatus of FIGS. **1** and **2** and by the rolls **120** and **170** in the apparatus of FIGS. **3** and **4**, may be determined by observation of the yarn as it travels across the heat contact surface of the heater. As pointed out above, an arcuate contact surface is preferred in the heater to enable the treatment of a wide variety of yarns without making machine modifications to accommodate to different yarn characteristics. The fact that the yarn is traveling through the apparatus at a high rate of speed makes it virtually impossible to measure the tension in the yarn without affecting the yarn tension by the very act of measuring.

In order to adjust the overfeed to obtain sufficient tension on the yarn to prevent pigtailing and tangling of the filaments, the travel of the yarn across the heater is observed as it is twisted by the false twist device. If the yarn is overly slack and excessively relaxed, the twist inserted in the yarn by the false twister causes excessive lateral travel of the yarn toward one edge of the heater surface, and passage through the whirler is impaired. on the other hand, if the feed rolls are adjusted to provide less than the desired overfeed, the contractile forces generated by the yarn by reason of its residence time in the heated zone tensions the yarn to an extent that the crimps are straightened. This condition is manifested by observance of the yarn travel across the heater in a tensioned state which does not permit the twist in the yarn to effect the desired lateral deflection of the yarn. Thus, the exact amount of the desired overfeed between 5 percent and 25 percent is thus obtained by observing the position of the yarn on the heater as it is affected by the false twist device. After the specific amount of overfeed is calculated, it may be reproduced without such empirical observaion and the amount of overfeed will remain at the same figure for all yarns which have the same characteristics, which are processed in accordance with the invention. It should be noted that if the machine speed is changed, the overfeed and the whirler parameters must be altered to accommodate to the different heat quantity imparted to the yarn by reason of the different residence time on the heater surface.

The foregoing condition of tension provided by the overfeed of the yarn is defined in the specification and in the claims as substantially tensionless and means tension sufficient to prevent pigtailing and tangling of the yarn filaments but not sufficient to straighten the crimps in the yarn.

The effect of treatment of the torque stretch yarn in accordance with this invention, as opposed to the prior art treatment, is illustrated in FIGS. **7, 8** an **9.**

With reference to FIG. **7**, it is apparent that the conventional torque stretch yarn exhibits a high degree of non-uniformity among the individual filaments of the yarn. The torque characteristics imparted to the filaments inherently produce loops L and pigtails P in certain filaments which tend to twist upon themselves to provide the well-known stretch characteristics of torque stretch yarns. In FIG. **8**, the pigtailing of the conventionally-set yarns has been reduced, but it is apparent that the crimps C individual filaments of yarns are not uniform, and there is a bunching of the filaments at F within the yarns. In the yarn of FIG. **9**, which is made in accordance with the present invention, the operation of the gentle air action upon the filaments has produced a uniformity in crimps C′ and an absence of filament bunching which substantially improves the overall uniformity of the treatment of the yarns, enabling maintenance of the desired uniform standards throughout.

The gentle injection of the stream of air tangentially along the cylindrical wall of the chamber parallel to the two flat end walls of the chamber provides a firm, yet gentle twisting force upon the yarn which, when the individual filaments of the yarn are separated by the air flow, effects a uniform treatment of these filaments to provide the desired counteracting torque. The gentle air pressure avoids concentration of forces which tend to disrupt the yarn bundles, at the same time providing a pressure which indeed separates the individual filaments of the yarn bundle without permitting the filaments to entangle both upon themselves and with each other.

Since the chamber is symmetrical and is cylindrical at both ends rather than being tapered, the air which is flowed into the chamber is caused to exit through both of the yarn passageways in the end walls. In this manner, any axial forces on the yarn tend to oppose one another within the yarn chamber without causing an unbalance of forces tending to either advance the yarn or retard the yarn movement through the chamber.

The treatment of the yarn in accordance with the present invention has been found to improve the uniformity of the yarn to an extent that the aggregate properties of the processed yarn provide a yarn which is more satisfactory than the yarn which is normally received from the processor.

For purposes of illustration, several samples of reduced torque set yarn produced according to the instant invention will now be discussed.

Example Number 1

The first sample, 70 denier 34 filament polyester yarn (Dacron, type 56) was processed on a Leesona 553/570 machine. Machine parameters were set as follows: first spindle speed = 270,000 RPM; primary twist = 85 turns per inch S; primary overfeed = 0 percent; secondary overfeed (overfeed across the second heater) = 17.0 percent; package overfeed (on take-up) = −5 percent; first heater temperature = 430° F; second heater temperature = 360° F. The second false twist means was the whirler and it was mounted downstream of the second heater and positioned in a manner to impart Z twist to the yarn. The manifold pressure used in the whirler was 2 pounds per square inch gauge. Dimensions of the whirler itself included a whirling chamber length of 0.375 inches, a chamber diameter of 0.662 inches, a nose length of 0.1875 inches and an air inlet diameter of 0.062 inches. The latter may be varied somewhat and inlet diameters as high as one quarter inch have been successfully tested.

The yarn produced when the above parameters were employed was collected on the take-up package and removed from the machine and a sample was wound into a skein. The standard Leesona Skein Shrinkate Test; Set Producedure (using a load of 0.00016 grams per denier) was performed on the skein and the values were skein shrinkage wet of 17.2 percent and skein shrinkage dry of 18.4 percent.

Additional yarn from the take-up package was knit into a sleeve on the standard Fabric Analysis Knitter with one needle removed to "drop a stitch" and make on one wale of the fabric quite visible. The torque angle of the fabric was measured by determining the angle between the visible wale and the longitudinal axis of the sleeve. The torque angle of the sleeve as knit was measured as 0°.

The fabric of FIG. **14** was made from a continuous piece of 70/34 polyester yarn, the bottom portion with the whirler operating and the top part with it turned off. This is possible with a pneumatic means. The pressure was increased to 3 pounds per square inch, adequate to reverse the torque angle of the fabric to a substantial extent. It can be noted that the voluminosity of the whirler fabric is greater than the section knit from standard set yarn.

Several packages of yarn made in accordance with this example were incorporated into a tricot fabric which was dyed and made into a garment. The dyed fabric exhibited a uniformity in color which avoided the streaks normally apparent in a tricot fabric made from set yarns of the prior art. The lofty hand and other tactile properties of the garment were comparable in many respects to garments produced by more expensive yarn and under much more rigid controls during the fabrication of the fabric.

Example Number 2

A second sample of yarn, 150 denier 34 filament polyester yarn (Dacron, type 56) was processed on a Leesona 553/570 machine with parameters set as follows: first spindle speed = 270,000 RPM; primary twist = 62 turns per inch S; primary overfeed — 0 percent; secondary overfeed =+ 15.75 percent; package overfeed = −5 percent; first heater temperature = 420° F; second heater temperature = 370°F. The dimensions of the whirler were the same as those used in processing the previous sample of 70/34 polyester. The air pressure was 1.9 pounds per square inch gauge.

Samples of this 150/34 polyester were taken with the whirler in operation and without the whirler in operation. These samples will hereinafter be referred to as "whirler yarn" and "standard yarn," respectively. Skeins were wound from the samples and sleeves were knit from the samples. The yarn samples, skeins and sleeves illustrated in FIGS. **8** to **13** were made with yarn of this sample. FIGS. **8, 10** and **12** illustrate the standard sample, and FIGS. **9, 10** and **13** illustrate the whirler sample. The following Table I relates to these samples of yarn.

TABLE I

Yarn Sample	% Skein Shrinkage Wet	Skein Shrinkage Dry	Torque Angle	Hanging Loop Torque %
Standard	17.0%	18.5%	+8°	90.64
Whirler	17.5%	19.1%	+1°	97.84

It can be seen that the torque angle as knit measured on the whirler sleeve was only + 1° while the torque angle measured on the standard sleeve was =8°. Thus, the standard sleeve illustrated in FIG. **12** after being subjected to dying moisture and temperature, and then drying exhibits a wale on the bias from the upper right to lower left. Such a sleeve is known as a Z fabric because the wale forms a portion of the letter Z (drawn on the photograph of the sleeve). The whirler sleeve in FIG. **13** has a Z torque angle almost equal to zero.

The skein shrinkage values were caluculated by using the standard Leesona Skein Shrinkage Set Yarn Test using a load of 0.00016 grams per denier to tension the yarn. This test is a standard test-known to those of ordinary skill in the art. (The Leesona Skein Shrinkage stretch Yarn test uses a weight of 0.0016 grams per denier). For convenience, a (2) gram weight is used and to distribute 2 grams at 0.00016 grams per denier, a total denier in the skein of 12,500 is required. The number of wraps for any denier on any size winding reel is computed as follows:

$$\text{Number of wraps} = \frac{12{,}500 \text{ denier}}{(\text{denier of sample})(2 \text{ ends/wrap})}$$

The number of wraps for 150 denier yarn is computed as follows:

$$\text{Number of wraps} = 12{,}500/(150)\ (2) = 42 \text{ wraps}$$

Skein shrinkage values of 30 percent and under are acceptable for set yarn. Smaller values are more desirable and much commercial set yarn has a skein shrinkage value of no greater than 20 percent.

The last column of the above Table 1 indicates values for "hanging loop torque, %" for the two samples of yarn. This value is calculated by spanning a sample of yarn horizontally between two jaws that are 100 centimeters apart and applying a standard weight of 600 milligrams at the 50 cm. mid-point of the sample. One jaw is then traversed toward the other stationary jaw at a constant rate. The value obtained is the number of centimeters traversed by the jaw when the standard weight begins to rotate under the influence of the torque in the yarn. As is apparent, a completely torque-free yarn would have a hanging loop torque figure of 100 percent and the less torque present in a sample, the closer the value to 100 percent. The hanging loop torque for the whirler sample of FIG. **9** was 97.84 percent while the value for the standard sample of FIG. **8** was 90/64 percent. The latter value indicates a much higher set yarn residual torque.

To obtain a fabric having a zero torque angle after dyeing and drying, it is necessary to impart a reverse torque to the yarn. There is latent torque in the yarn after setting, and this latent torque is activated by dyeing and drying or other finishing operations. For example, the unfinished fabric of this example exhibited a torque angle of +5° in the standard yarn fabric and a torque angle ob −3° in the whirler fabric. The finishing conditions activated the latent torque and generated the torque angles indicated above.

To develop a zero torque angle in the finished fabric, the whirler pressure was increased to 2.2 pounds per square inch gauge. The unfinished jersey-knit whirler fabric had a torque angle of −5°, equal and opposite to the standard fabric torque angle of +5°. After being subjected to finishing conditions, the whirler fabric exhibited a zero torque angle as apposed to the +8° torque angle in the standard fabric.

A visual inspection of the whirler sample of FIGS. **9** and **11** indicates a much higher bulk in the yarn than is present in the standard sample of FIGS. **8** and **10.** Care should be taken to avoid confusion between a true pigtail and a simple loop in a filament. Attention is directed to the left side of FIG. **9** where several filaments appear to have loop-like deformations formed therein. These deformations appear as loops because of the angle at which they are viewed in a two dimensional photograph.

FIGS. **8** and **9** are photographs of yarn samples that are the same scale as each other but are both of lesser magnification than FIG. **7.** It is apparent that the pigtail deformations are no longer present in these figures as both of the yarn samples of FIGS. **8** and **9** are set yarns.

The photographs of FIGS. **8** and **9** were taken with the yarn at the same tension and the much greater bulk of the whirler sample is readily apparent by comparing the two figures. Interfilament spacing is increased and the filament bundle diameter is greater in the whirler sample of FIG. **9.**

Additional evidence of increased bulk is evident from an inspection of the skeins of FIGS. **10** and **11.** The diameter of the whirler test skein of FIG. **11** is much greater than the diameter of the standard test skein of FIG. **10.**

The volumes of the skeins have been calculated for both the 70/34 polyester and 150/34 polyester samples discussed above. In each instance, the air flow was shut off to process a standard sample and then turned on to process a whirler sample. With the volume of the standard skeins taken as a base value of **100%**, the results are tabulated below in Table II.

Table II

Yarn Sample	% Volume
70/34 standard	100
70/34 whirler	244
150/34 standard	100
150/34 whirler	301

Thus it can be seen that the volume or bulk or voluminosity of the skeins was greatly increased when the yarn was processed in accordance with the teachings of the instant invention.

Example Number 3

A third sample of yarn was prepared for the purpose of knitting a commercial tricot fabric. This sample was a 150 denier 34 filament polyester yarn (Dacron, type 56) that was processed on a Leesona 555/570 machine with parameters set as follows: first spindle speed = 270,000 RPM; primary twist = 61.7 turns per inch S; primary overfeed 0 percent; secondary overfeed = +15.75 percent; package overfeed = −5 percent; first heater temperature = 430° F; second heater temperature 415°F. The whirler was positioned to impart Z twist and whirler manifold pressure = 1.9 pounds per square inch gauge. The dimensions of the whirler were the same as previously disclosed with reference to the **70** denier sample of yarn.

This yarn was beamed and then knit on a 20 gauge two-bar tricot machine. The fabric produced was inspected in the greige and after dyeing. Stitch clarity and uniformity of the tricot fabric was superior to other fabrics made from set yarn. The fabric showed an improved loft because of the increased bulk in the yarn. In spite of the low amount of second twist developed by the whirler, the torque angle in this tricot fabric was substantially 0°, in the greige as was the case in the dyed tricot fabric.

Example Number 4

A fourth sample of yarn was prepared to investigate the properties of nylon torque stretch yarn reprocessed in accordance with the present invention. This sample was a 100 denier 34 filament type 66 nylon that was processed on the Leesona 555/70 machine with parameters as follows: first spindle speed = 270,000 RPM; primary twist 65 turns per inch S; primary overfeed = 0 percent; secondary overfeed =+15.75 percent; package overfeed =−5.0 percent; first heater temperature =390° F. (instead of the usual 435° F); second heater temperature = 410° F. The whirler was mounted downstream of the second heater and positioned to impart Z twist to the yarn with manifold pressure in the whirler of 8 pounds per square inch gauge. The whirler was of the same dimensions as the whirlers of the previous examples.

The nylon yarn was collected on take-up packages and knit into a sleeve as in the previous examples and the torque angle as knit was measured as 0°.

The regulation of the heater temperatures to reduce the first heater temperature and increase the second heater temperature, along with the increased air pressure in the whirler made it possible to produce a nylon yarn with substantially no residual torque. It is theorized that when processing yarns such as nylon, the use of lower heater temperatures in the first heater is advantageous because of the peculiar thermal characteristics, such as second order transition. Of necessity the thermal characteristics of each yarn being processed must be taken into consideration and consequently the temperature of the first heater must be such that the torque stretch yarn remains obedient to the optimum second heater temperature during low level pneumatic reverse false twisting. Accordingly the present invention may enable thermal processing of yarns to make them suitable for end uses which were heretofore considered unsuitable with such yarns.

In the present invention, it is believed that the twisting action of the second false twist means cooperates with tha action of the heat supplied by the second heater and correlated tension in a manner that may be described as a combination of mechanial working and heat working or annealing of the torque stretch yarn. The torque stretch yarn is characterized by a certain degree of internal stress attributable to the action of the first false twist device when it untwisted the yarn that had just had a twist heat-set in the heating and cooling zones. The heat supplied by the second heater minimizes the torque by relieving stress in the yarn by annealing and the second twisting physically rearranges the filaments of the yarn to reduce the torque yet enhance the bulk.

Additionally, the action of the whirler fluid on the filament bundle of the yarn separates the filaments in a manner that increases the bulk, voluminosity and covering power of the yarn even more than twisting alone.

The twist imparted by the second false twist means should be of a nature to reduce the torque, enhance the bulk and avoid an over-compensation that would impart undesirable stretch properties to the set yarn.

It should be understood that when the terms such as reducing or diminishing are used with reference to the residual torque, the terms are used in their mathematical sense and not in an absolute sense. Thus, although a number with a value of −1 (negative one) is actually mathematically larger than a number with a value of −6 (negative six), a yarn with a torque angle value of −1° has a torque that has been diminshed when compared with a yarn with a torque angle value of −6°.

It should be apparent that the present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof, all of which are intended to be encompassed by the appended claims.

We claim:

1. A method of making set yarn by modifying the torque of an advancing multifilament false-twist textured yarn having an initial torque resulting from having been false twisted to a preselected twist under controlled conditions of heat and tension to produce the false-twist textured yarn, the torque in said yarn having a tendency when the yarn is completely relaxed to cause the development of crimp and pigtail deformations which method comprises overfeeding the false-twist textured yarn through a portion of its path of travel which includes heating and cooling zones so that the yarn is not completely relaxed but is substantially tensionless when heated and while being cooled in said heating and cooling zones respectively, said substantially tensionless condition permitting development of crimp but not development of pigtail deformations, passing the substantially tensionless yarn after its passage through the heating zone through a fluid-whirling chamber, engaging the yarn while in said chamber with a stream of low pressure fluid having a component operable to false twist the yarn while it is in the heating zone in the direction opposite the aforesaid preselected twist, controlling the pressure of said fluid stream in correlation to the rate of travel of the yarn to false twist the yarn a substantially less number of turns than the aforesaid preselected twist so as to provide the aforesaid modification of torque in said yarn which upon complete relaxation of said yarn permits development of crimp without generating pigtail deformations in the yarn, advancing the yarn after passage through said chamber, and collecting the yarn beyond the aforesaid portion of its path of travel.

2. A method of improving the uniformity of yarn comprising modifying the torque of a multifilament yarn according to the steps of claim 1, wherein said step of controlling the fluid stream pressure balloons the yarn in said fluid-whirling chamber and effects false twisting of the yarn less than 25 percent of the preselected twist producing the false-twist textured yarn.

3. A method of making set yarn according to claim 1 wherein said step of controlling the fluid stream pressure separates the individual filaments of the multifilament yarn to permit development of the crimp in the filaments without permitting entanglement of the filaments upon themselves and with each other.

4. A method according to claim 1 wherein said modification of the torque produces a set yarn with substantially zero torque.

5. A method according to claim 1 wherein said modification produces a set yarn having torque opposite to the initial torque of the false-twist textured yarn.

6. A method according to claim 1 wherein said engagement of the yarn by the stream of fluid in the fluid-whirling chamber is effected by providing a cylindrical inner surface in said chamber and directing said stream of fluid along said surface in a tangential direction in a plane perpendicular to the path of travel of the yarn through said chamber.

7. A method according to claim 6 wherein said stream of fluid is discharged from said fluid-whirling chamber through oppositely-directed, equally-restricted axial passageways having a common axis, said yarn path also passing through said passageways.

8. A method according to claim 1 wherein said yarn is heated in said heating zone by passing in contact with an arcuate heated surface in a path providing sliding engagement of the yarn upon the arcuate surface.

9. A method according to claim 1 wherein said cooling zone extends into said fluid-whirling chamber and wherein said fluid stream is air from a low-pressure blower.

10. A method according to claim 1 wherein said low-pressure stream of fluid is an air stream generated by blowing air without compressing it.

11. A method according to claim 10 wherein said low pressure is 30 pounds per square inch or less.

12. A method according to claim 1 wherein said step of controlling the pressure to false twist the yarn a substantially less number of turns than the aforesaid preselected twist is effective to false twist the yarn less than 25 percent of the aforesaid preselected twist.

13. A method according to claim 1 wherein said set yarn is made continuously with the production of the false-twist textured yarn including the preliminary step of producing the false-twist textured yarn from sup-

plied thermoplastic yarn immediately prior to said step of feeding said yarn through the heating zone whereby said yarn is travelled without interruption from its supplied state through its conversion into a set yarn having modified torque.

14. A method of making and advancing set false-twist textured yarn having controlled torque from supplied thermoplastic multifilament yarn which comprises continuously feeding the supplied multifilament yarn through a first heating zone to impart a controlled amount of heat and tension to the yarn therein, mechanically false twisting said yarn to a preselected twist under said controlled tension and heat to impart a torque and crimp to said yarn, cooling the yarn to set said torque and crimp therein and thus produce a false-twist textured yarn having a tendency when the yarn is completely relaxed to cause the development of pigtail deformations, overfeeding said false-twist textured yarn continuously through a portion of its path of travel which includes second heating and cooling zones so that the yarn is not completely relaxed but is substantially tensionless when heated and while being cooled in said second zones, said substantially tensionless condition permitting development of crimp but not development of pigtail deformations, passing the substantially tensionless yarn after its passage through the second heating zone through a fluid-whirling chamber, engaging the yarn while in said chamber with a stream of low pressure fluid having a circumferential component operable to false twist the yarn while it is in the heated zone in the direction opposite to the aforesaid preselected twist, controlling the pressure of said fluid stream in correlation to the rate of travel of the yarn to effect a separation of the filaments of said yarn without entanglement and to twist the yarn a substantially less number of turns than the aforesaid preselected twist imparted by said first-mentioned false twisting, to provide a controlled torque in said yarn which upon complete relaxation of said yarn permits a crimp development without generating pigtail deformations in the yarn, advancing the yarn after passage through said chamber, and collecting the yarn beyond the aforesaid portion of its path of travel.

15. A method according to claim **14** wherein said stream of low pressure fluid is directed around said yarn in a plane perpendicular to the path of travel of the yarn through said fluid-whirling chamber to balloon the yarn and effect false twisting of the yarn less than 25 percent of the preselected twist.

16. In a method of modifying thermoplastic set yarn to reduce its torque and enahnce its bulk comprising the steps of producing set yarn with a double heater set yarn machine and reverse false twisting the yarn as it is being overfed through the second heater, said reverse false twisting being controlled to produce in the yarn in the second heater a number of twists per unit length that is no more than 25 percent of the twists per unit length imparted to the yarn during the first false twisting process, said overfeed through the second heater being in the range of 5 to 25 percent, the improvement wherein said reverse false twisting is effected in a fluid-whirling chamber by engaging the overfed yarn with a stream of low-pressure fluid having a component operable to effect said reverse false twisting the yarn, and wherein said overfeeding is operable to render said yarn substantially tensionless so as to assure that crimp deformations are present in the yarn but no pigtail deformations caused by torque are present in the yarn, and including the step of withdrawing the yarn away from said fluid-whirling chamber to provide and maintain said substantially tensionless condition of the yarn after its engagement by said stream of low-pressure fluid, and thereafter collecting said withdrawn yarn with a separately controlled tension.

17. In a crimped set multifilament thermoplastic yarn having a crimped configuration but noted for its absence of torque-induced pigtails when in a relaxed condition; said yarn when subjected to skein shrinkage yarn test using a weight of 0.00016 grams per denier having a wet and dry skein shrinkages of under 30 percent the improvement wherein said yarn is a multifilament false-twist textured yarn which when in a relaxed condition has its individual filaments crimped and physically rearranged relative to each other without substantial pigtails or entanglement in the individual filaments as a result of reverse false twisting by a stream of low-pressure air directed circumferentially therearound to impart a skein volume in the range of over 150 percent up to 300 percent when the volume of a standard skein is taken as 100 percent.

18. A yarn according to claim **17** wherein the yarn comprises a polyester yarn.

19. A yarn according to claim **17** wherein the yarn comprises a nylon yarn.

20. A fabric comprising a yarn according to claim **17,** said yarn having its filaments further rearranged as a result of its fabrication.

21. A fabric according to claim **20** wherein said fabric is a knit tricot.

22. A fabric according to claim **20** wherein said fabric is a knit jersey.

23. A garment comprising a fabric in accordance with claim **20.**

24. A fabric comprising false-twist textured yarn, said fabric having a zero torque angle, the false-twist textured yarn when relaxed having a reverse torque as a result of reverse false twisting and having its individual filaments crimped and physically rearranged relative to each other without substantial pigtails or entanglement in the individual filaments, said fabric exhibiting a reverse torque angle prior to finishing, and upon finishing with application of heat exhibiting a zero torque angle.

25. A method of producing a fabric with a zero torque angle comprising the steps of producing a set yarn from a false-twist textured yarn in accordance with claim **1** wherein the torque is modified to a degree sufficient to provide a low torque opposite to the aforesaid initial torque of said false-twist textured yarn, incorporating said set yarn into a fabric, and finishing said fabric under conditions to produce said zero torque angle in the fabric after finishing.

26. Apparatus for making set yarn by modifying the torque of an advancing false-twist textured multifilament thermoplastic yarn comprising means defining a heated zone for passage of the yarn therethrough, said yarn having a tendency when completely relaxed to develop crimp and pigtail deformations, means for heating said zone to a predetermined temperature, a fluid-whirling chamber for passage of the yarn therethrough after passage through said heated zone, means for overfeeding the torque stretch yarn through a portion of its path of travel which includes the heated zone and a subsequent cooling zone so that the yarn is not completely relaxed but is substantially tensionless while in said heated and cooling zones, said substantially tensionless condition permitting development of the crimp but not the pigtail deformations, means to direct a stream of low-pressure fluid into the fluid-whirling chamber in a direction to false twist said yarn opposite the false twist of the false-twist textured yarn, pressure control means operable to control the pressure of said fluid stream to rearrange the filaments without causing entanglement between the filaments and to false twist the yarn the number of turns required to provide the desired modification of the torque in the advancing yarn, means for advancing the yarn after passage through the chamber, and yarn control means operable to maintain the yarn in said substantially tensionless condition during passage through said portion of its path of travel and to collect the yarn beyond said portion of its path of travel.

27. Apparatus according to claim **26** wherein said fluid-whirling chamber has a cylindrical side wall with its axis disposed in alignment with the yarn path therethrough, said means to direct low pressure fluid into said chamber being operable to provide a circumferential component which balloons the yarn in said chamber.

28. Apparatus according to claim **27** wherein said means to direct a stream of low-pressure fluid into said chamber includes an inlet passageway disposed substantially tangential to said cylindrical side wall and terminating in an inlet port in said side wall, and a blower connected to said passageway for blowing air into said chamber without compressing the air.

29. Apparatus according to claim **28** wherein said inlet passageway has an axis disposed in a plane perpendicular to the axis of said cylindrical side wall.

30. Apparatus according to claim **29** wherein said chamber has end plates perpendicular to the axis at the cylindrical wall at each end thereof, said plates having axial bores therein for the passage of yarn through said chamber, said bores being of smaller internal diameter than said chamber, the fluid inlet passageway being positioned midway between said end plates to render said device symmetrical and reversible.

31. Apparatus according to claim **30** wherein said end plates have nose sections projecting exteriorly therefrom along the cylindrical axis to provide an extended length to said yarn passage bores.

32. Apparatus according to claim **25** wherein said bores at their inner end within said chamber are flared to assist the formation of the balloon of yarn within said chamber between said flared bore ends.

33. Apparatus according to claim **26** wherein said pressure control means comprises a pressure conduit for supplying low-pressure fluid, a pressure regulator for said conduit, and a pressure-indicating gauge.

34. Apparatus comprising a series of yarn treating stations, each station being made in accordance with claim **21** said pressure control means comprising a common pressure conduit connected to the means to direct fluid circumferentially into the fluid-whirling chamber of each station, a pressure regulator for said conduit, and a pressure-indicating gauge.

35. Apparatus according to claim **26** wherein said chamber is in line with said heated zone so that said low-pressure fluid is effective to twist the yarn while heated in said heated zone and to untwist the yarn when it is passed through said chamber, said chamber being spaced apart from said heater a distance to provide a cooling zone to cool the yarn prior to untwisting.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,785,135 Dated January 15, 1974

Inventor(s) Warren A. Seem, Nicholas J. Stoddard and Robert W. Stoddard

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 16, "tecnique" should be --technique--;

Column 2, line 37, "are" should be --were--;

Column 4, line 20, "in" should be --is--;

Column 4, line 32,33 "decreases" should be --increases--;

Column 7, line 54, "testile" should be --textile--;

Column 8, line 2, "thrid" should be --third--;

Column 9, line 18, "1" should be --131--;

Column 10, line 13, "circuit" should be --conduit--;

Column 10, line 17, "wirler" should --whirler--;

Column 10, line 28, "of" (second occurrence) should be --or--;

Column 13, line 37, "Producedure" should be --Procedure--;

Column 14, line 7, "overfeed - 0 percent" should be

--overfeed = 0%--

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It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 14, line 22, "10" should be --11--;

Column 14, line 35, "=8°" should be --+8°--;

Column 14, line 43, "caluculated" should be --calculated--;

Column 14, line 46, "test-known" should be --test well-known--;

Column 14, line 49, "a (2) gram" should be --a two (2) gram--;

Column 15, line 16, "90/64" should be --90.64--;

Column 15, line 26, "ob" should be --of--;

Column 17, line 14, "tha" should be --the--;

Claim 16, line 2, "enahnce" should be --enhance--;

Claim 32, line 1, "25" should be --30--;

Claim 34, line 3, "21" should be--26--;

Signed and sealed this 22nd day of October 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents