United States Patent [19]

Tecce et al.

[11] **3,785,136**

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

[54] **APPARATUS AND PROCESS FOR PRODUCING TORQUE CONTROLLED VOLUMINOUS SET YARN AND YARN AND FABRIC PRODUCED THEREBY**

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[22] Filed: **May 10, 1971**

[21] Appl. No.: **141,622**

[52] **U.S. Cl.** ..... **57/34 HS,** 57/77.42, 57/140 R, 57/157 TS

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

[58] **Field of Search** ..... 57/34 R, 34 HS, 77.3, 57/77.42, 157 R, 157 TS; 28/72 HR

[56] **References Cited**

UNITED STATES PATENTS

3,041,814	7/1962	Held	57/34 HS
3,137,119	6/1964	Crouzet	57/34 HS
3,166,881	1/1965	Servage	57/34 HS

FOREIGN PATENTS OR APPLICATIONS

302,085	12/1917	Germany	57/77.42

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[57] **ABSTRACT**

Disclosed is a method and apparatus for producing a torque-controlled voluminous set yarn. False twisting means are employed to impart a relatively low number of twists per inch to a torque stretch yarn passed under low tension in the region of a yarn heater. The covering power of the yarn, i.e., the bulk or voluminosity of the yarn, thus produced is enhanced and residual torque in the yarn is controlled. Also disclosed is a set yarn with high bulk and reduced torque characteristics and a fabric produced therefrom.

11 Claims, 11 Drawing Figures

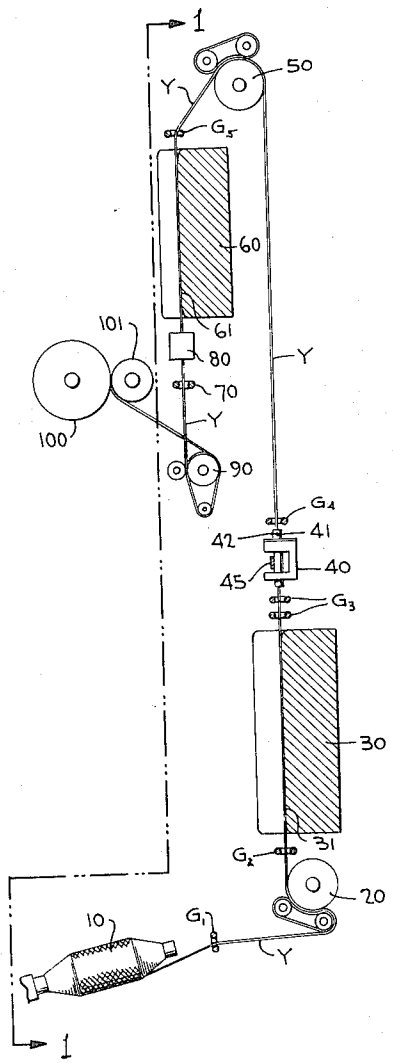

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FIG. 1

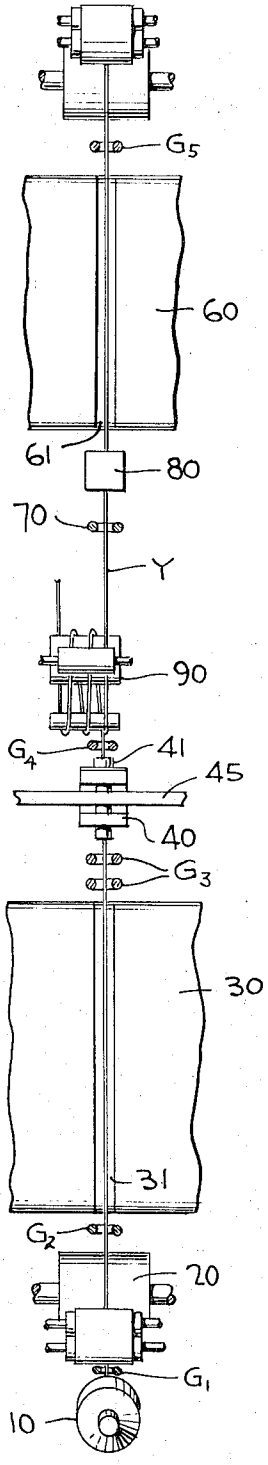
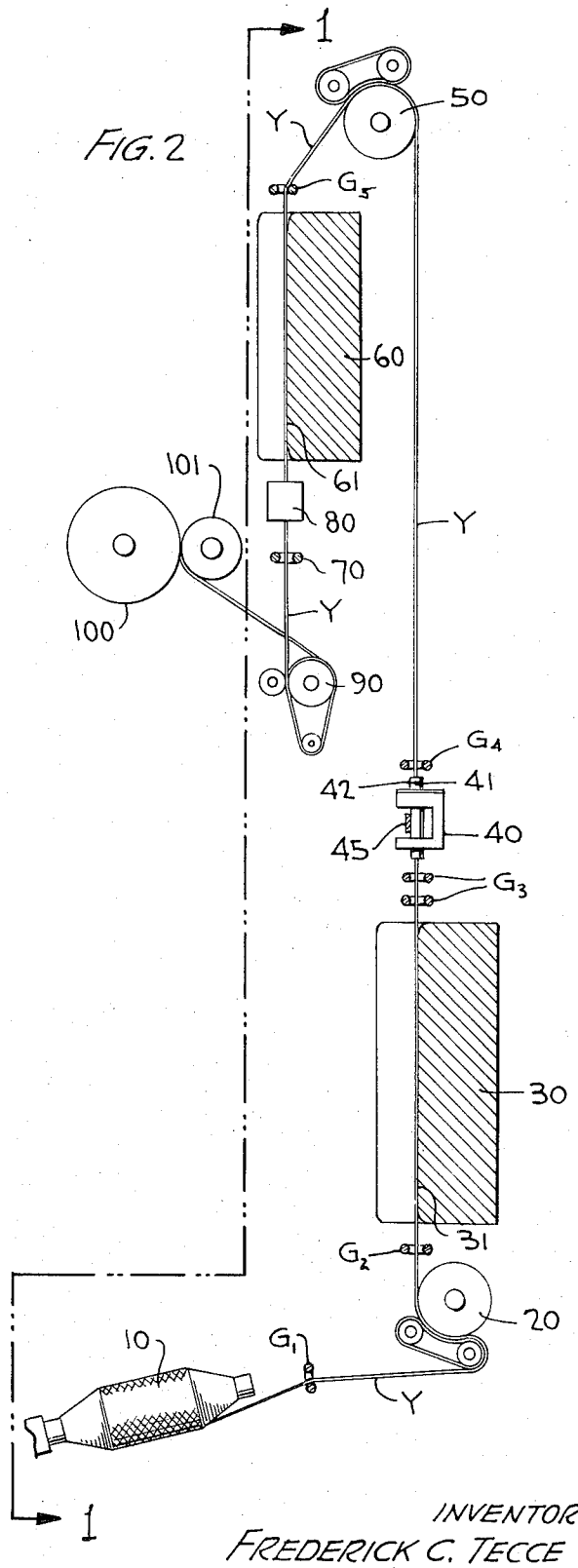


FIG. 2



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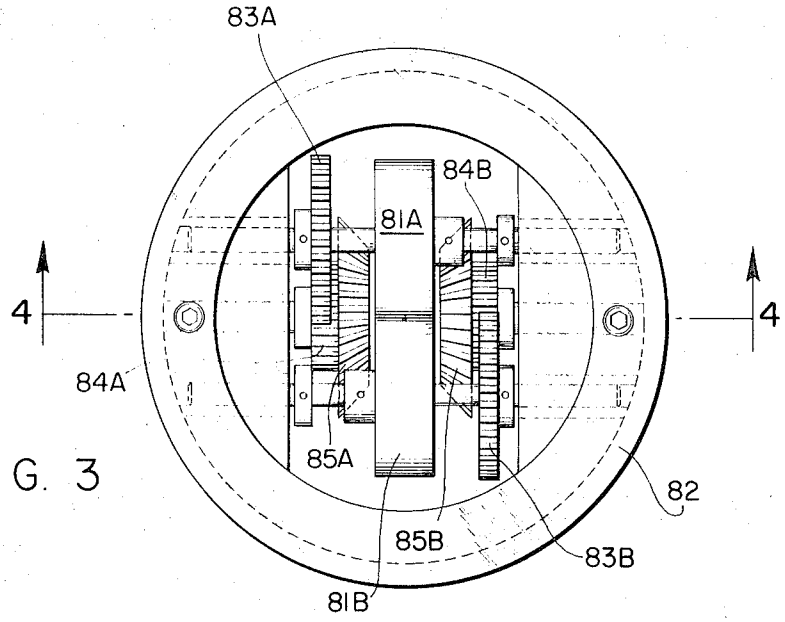

FIG. 3

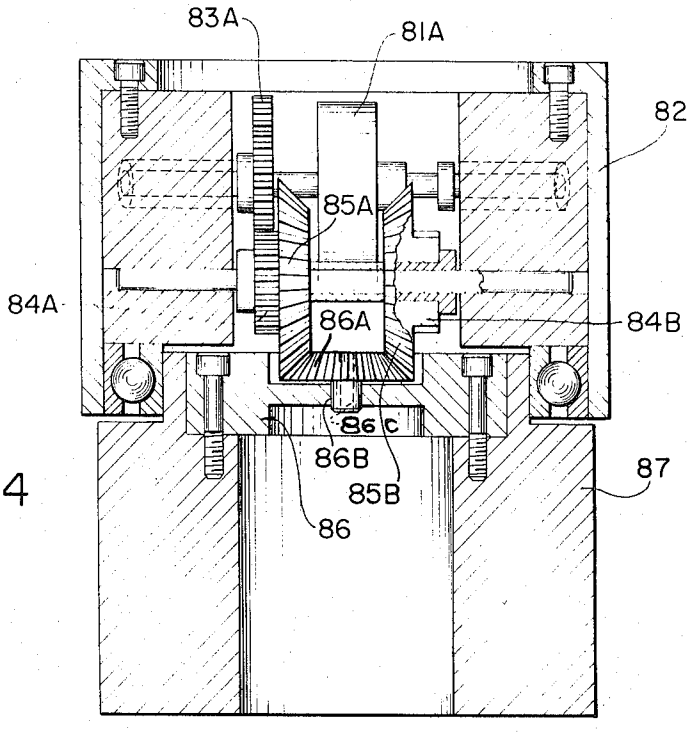

FIG. 4

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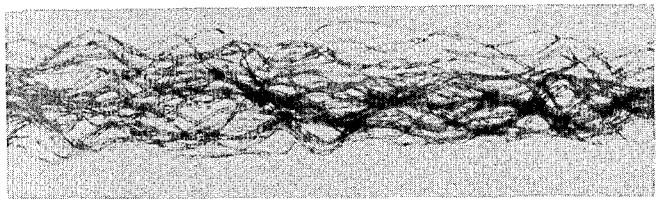

FIG. 5

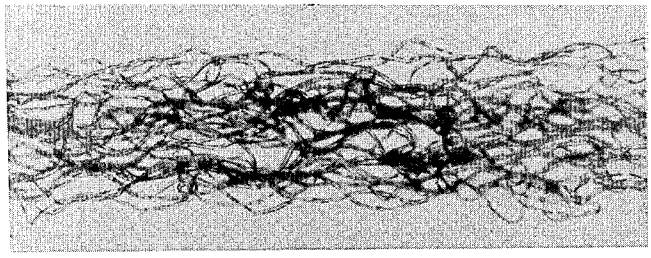

FIG. 6

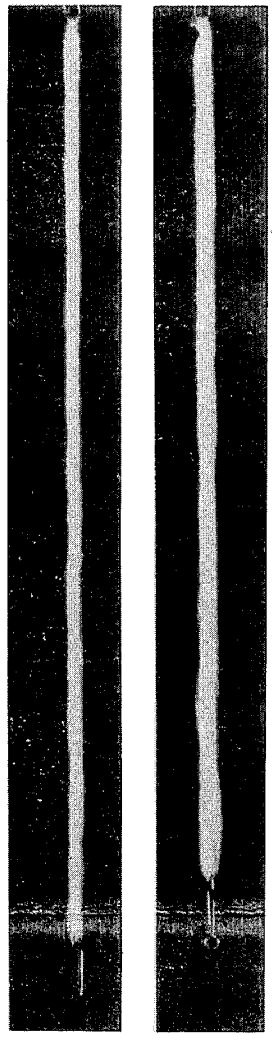

FIG. 7

FIG. 8

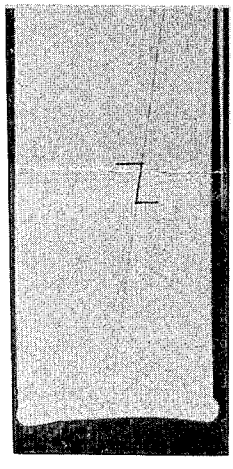

FIG. 9

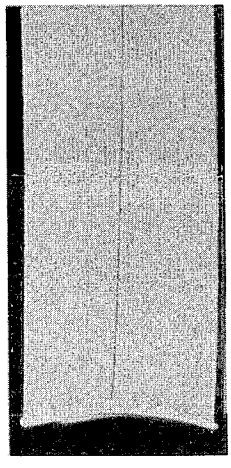

FIG. 10

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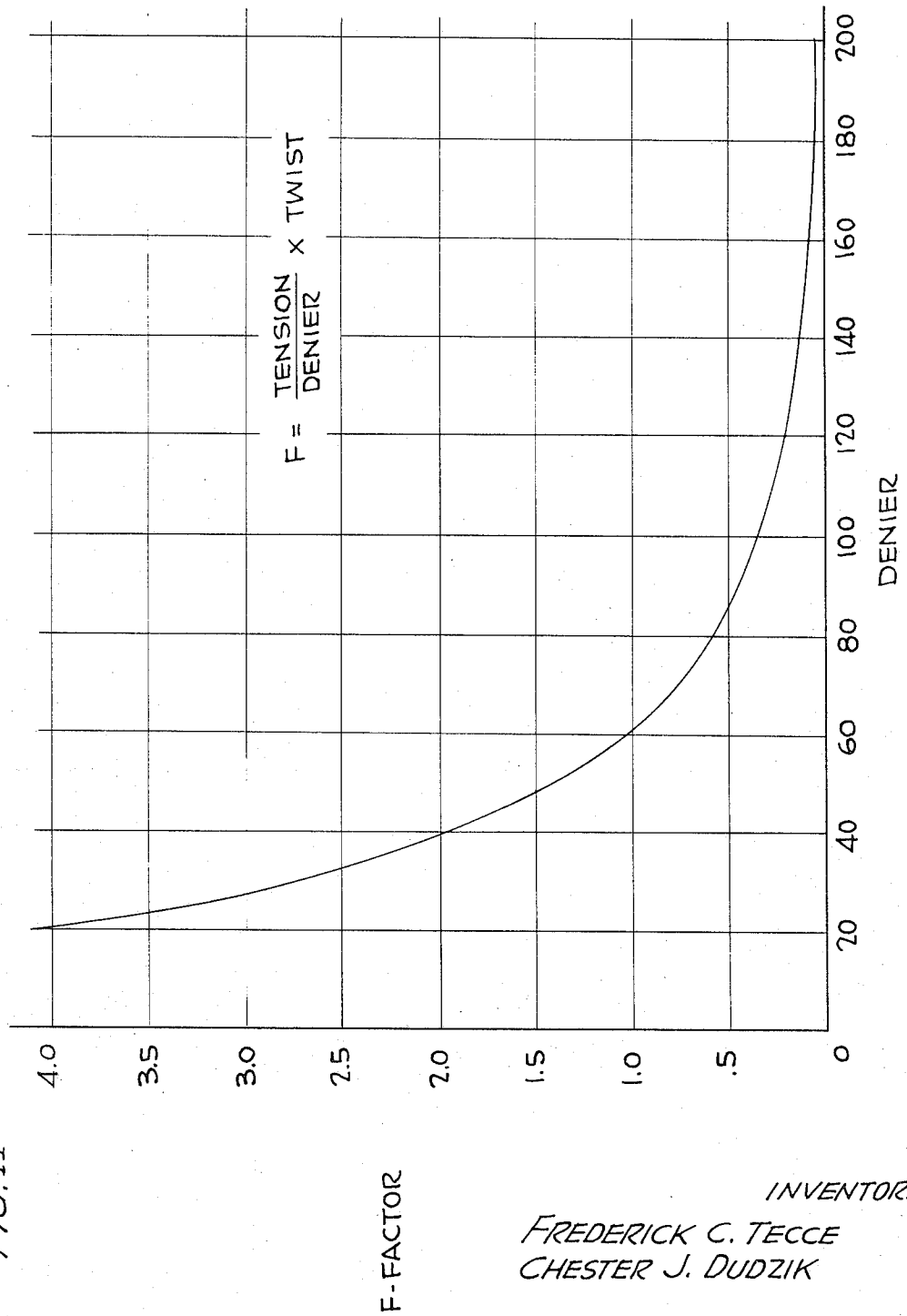

FIG. 11

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APPARATUS AND PROCESS FOR PRODUCING TORQUE CONTROLLED VOLUMINOUS SET YARN AND YARN AND FABRIC PRODUCED THEREBY

BACKGROUND OF THE INVENTION

The present invention relates to a process and apparatus for controlling residual torque and 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, these 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 technique 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 fully, 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 the 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 re-appear.

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 due to inter-fiber friction and filament phasing. Some filaments tend to work in unison while others tend to oppose one another. Stresses are therefore nonuniformly relieved. The result of such forces combining is to cause voids or sections of yarn with small cross-section; whereas the opposite occurs when 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. 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. The yarn is then heat treated in this configuration by the application of heat, pressure and moisture in the autoclaving step. The foregoing method is in widespread commercial use at the present time. As is apparent, this is a discontinuous or batch method of producing set yarn.

A method for producing more uniform set yarn is one in which the process is continuous. This is, torque stretch yarn is drawn directly from a source (such as a package or directly from the first false twist means) under sufficient tension so that it is first straightened and is then overfed at a given value across a yarn heater. The overfeed across the heater is adjusted so that the yarn relaxes a sufficient amount to permit the formation of the crimp in the yarn yet prevent the formation of all or substantially all of the torque-induced pigtails. When the yarn is drawn over the second heater under controlled conditions of temperature and tension the stresses which were non-uniformly relieved in the initial untwisting are caused to be made permanent, thereby resulting in a non-uniform yarn which results in a non-uniform appearing fabric.

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 to the point where a crimped configuration exists, and while in this configuration is then heated and cooled so that a crimped configuration is retained in the yarn.

Alternatively, set yarn may be produced on a machine that combines the operation that produces "torque stretch yarn" and the subsequent processing of this yarn into "set" yarn. A strand of feed 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 then advances to a second heater and is overfed across the second heater. The overfeed is controlled 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. Such a machine is known in the trade as a double heater set yarn machine. One machine for performing this second described process is the combination of a Model 570 attachment and

a Model 553 or 555 false twist machine, all produced by Leesona Corporation.

A problem in the production of set yarns is that of residual torque. Torque is partially removed during the annealing step in the subsequent or second heater treatment. However, residual torque remains in the yarn which is readily detectable by a number of simple tests. As an example of such a test, one may grasp a one meter 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 7 turns.

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 a fabric is the knitting of a test sleeve of fabric with a Single Jersey knit. A single Jersey knit is a knit that will clearly illustrate the effects of torque in the yarn. The angular orientation of the wales of the sleeve will be 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 angle increases with an increase in the torque in the yarn. It is desirable to minimize the torque angle when producing a commerical fabric, partially when the yarn is wound on a beam for use in a warp knitting process such as, for example, a tricot process.

SUMMARY OF THE INVENTION

According to the instant invention, false twist means are provided to impart a relatively small number of twists per inch to torque stretch yarn as it is overfed 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.

The number of twists per inch imparted to the yarn by the second false twist means is of substantially lesser number than the number of turns of twist imparted to the yarn by the first false twist means. 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 would be imparted to the yarn by the second false twist means. 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.

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 according to the instant invention will, in combination with the heat of the second heater, diminish the yarn torque more than the torque is diminished by heat alone yet will retain the crimp in the yarn at substantially the level attained by heating alone.

The present invention is intended to permit the filaments to assume a more random condition within the yarn bundle while they are being subjected to the second successive twisting, heating, cooling and untwisting under correlated tension. This is achieved by twisting the yarn in a direction opposite to that in which it tends to rotate.

Several means to impart a second twist are disclosed. For example, a conventional false twist spindle as the one disclosed in U.S. Pat. No. 3,044,247 may be positioned downstream of the second yarn heater in a position such that the twist trapping pin in the spindle blade is directed in a downstream direction. Appropriate driving means such as a motor driven driving belt would be associated with such a false twist spindle. For purposes of subsequent discussion this just discussed false twist spindle would be referred to as the second false twist spindle or twisting means, inasmuch as it may be used on the same machine on which torque stretch yarn is made by the action of a first false twist spindle.

Another second false twist means may be a set of pinch rolls mounted on a cage. The cage will rotate about the axis of the traveling yarn to impart false twist thereto while the pinch rolls rotate about their own respective axes to advance the yarn.

This cage would be located in the same position as the previously discussed second false twist spindle and the direction of rotation as well as the speed of rotation of the cage about the axis of the traveling yarn would control the hand and number of twists imparted to the yarn in the region or zone of the second heater.

During operation, the twist imparted by the second false twist means will travel upstream across a yarn heater. For purposes of subsequent discussion this just-discussed heater would be referred to as the second heater, inasmuch as it is often used on the same machine which torque stretch yarn is made by the action of a first false twist spindle that twists yarn in the region of a first heater.

The second heater will have 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 will be substantially straightened. By operating these rolls at different 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 set yarn configuration. For the present invention best results are obtained if the overfeed is in the range of 5 to 25 percent. If the process of the instant invention is performed with an overfeed below a value of 5 percent, the yarn tension is such that little or no crimp-like deformations are permitted to form in the yarn. With an overfeed above a value of 25 percent, the yarn tension is such that it is difficult to twist the yarn with the second false twist means and pigtails begin to form.

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

Under proper operating conditions, yarn so treated will exit 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 zero torque yarn that will knit into a fabric that has improved hand and covering power and that has a small torque angle.

It is an object of this invention in some instances to reduce torque in yarn while also enhancing the covering power per unit of weight of the yarn.

Over the years, notable workers in the art have recognized that reverse false twisting yarn will modify its torque characteristics, but such knowledge has not been put to any practical use in connection with set yarns apparently because long experience with the false twist process itself and certain widespread beliefs regarding necessary parameters for operation of a false twisting means have obscured the facts that make practical and useful a means and process for the second false twisting in the reverse direction of a set yarn, namely, the utilization of a heretofore unused combination of low tension and reduced level of reverse false twisting.

Other objects of the instant invention will be apparent to those skilled in the art from a consideration of this specficiation and claims, taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic elevation of apparatus employed to continuously process set yarn as seen on plane 1—1 of FIG. 2.

FIG. 2 is a schematic elevation of apparatus employed to continuously process set yarn.

FIG. 3 is a top view of a second false twist means that includes yarn pinch rolls mounted on a rotating cage.

FIG. 4 is a sectional side view of the second false twist means of FIG. 3, taken on plane 4—4 of FIG. 3.

FIG. 5 is a photograph of a relaxed set yarn bundle.

FIG. 6 is a photograph of a relaxed reduced-torque set yarn bundle produced according to the instant invention.

FIG. 7 is a photograph of a test skein wound from set yarn.

FIG. 8 is a photograph of a test skein wound from reduced torque set yarn produced according to the instant invention.

FIG. 9 is a photograph of a test sleeve of fabric which is knit from set yarn, and has a torque angle other than zero.

FIG. 10 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.

FIG. 11 is a graph showing a relationship between the value of yarn denier and the value of an F factor defined by the equation F = tension/denier × twist.

DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

In this description the term yarn will be understood to embrace all textile strand-like materials, including mono- and multi-filament yarns that are thermoplastic by composition or that have been rendered capable of being set in a functional deformed position by heating and cooling.

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

With particular reference to FIG. 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 spindle blade 41 of the first false twist spindle 40 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 and first spindle. Yarn Y is then passed in contact with heated surface 61 of the second heater 60. Yarn Y is then passed through second false twist means 80, through guide means 70, passed around a third set of feed rolls 90 and on to take-up package 100 which is driven by cork roll 101.

Yarn Y travels across the first heater 30 in a direction from first feed rolls 20 toward false twist spindle 40, or with specific reference to FIG. 2, in an upward direction. Yarn Y travels across the second heater 60 in a direction from second feed rolls 50 toward false twist means 80 or, with specific reference to FIG. 2, in a downwardly direction. Feed rolls 50 and 90 may be considered the first and second feed rolls respectively relative to second heater 60. These feed rolls are located so that one is upstream and one is downstream of the heater.

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, defined in the following manner:

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

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.

As a first embodiment of false twisting means 80, a conventional false twist spindle may be employed and may be of the same type as false twist spindle 40. It is normally positioned, with specific reference to FIG. 2, so that the pin (corresponding to pin 42 in spindle 40) is pointing in a downwardly direction. Drive belt means may be employed to rotate such a false twist spindle in a manner similar to that of drive belt 45 and its cooperation with false twist spindle blade 41.

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 would be rotated in a direction to impart a substantially lesser number of turns of Z twist to the yarn in the region of heater 60.

FIGS. 3 and 4 illustrate another embodiment of the second false twist means. This false twist means is also designed as element 80 in FIGS. 1 and 2.

Yarn strand Y passes between a set of two pinch rolls 81A and 81B which are mounted for rotation about their own axes on shafts that are rotatably mounted on cage 82. Cage 82, in turn, in mounted on lower cage mount 87 in a manner that will permit relative rotary motion between cage 82 and lower cage mount 87. Lower cage mount 87 is rigidly attached to the main machine in FIGS. 1 and 2 and cage 82 may be belt

driven to rotate about an axis defined by the yarn passing therethrough.

Pinch rolls **81A** and **81B** are rotated toward each other by means of driven gears **83A** and **83B**. Driven gear **83A** is mounted on the same shaft or axle as pinch roll **81A** and a corresponding relationship exists for gear **83B** and roll **81B**.

Driven gears **83A** and **83B** draw their power from driving gears **84A** and **84B**. These driving gears mesh with driven gears **83A** and **83B** and draw their power from bevel or helical gears **85A** and **85B** which are mounted on the same shafts as driving gears **84A** and **84B**, respectively. Helical gears **85A** and **85B** are, of course, capable of independent rotation, relative to each other. Helical gears **85A** and **85B** are driven by gear **86A** which is rigidly attached by means of hollow pins **86B** and gear support member **86** to lower cage mount **87**. Both gear **86A** and pin **86B** have a bore **86C** formed therethrough to permit passage of the yarn.

Because lower cage mount **87** is rigidly attached to the main machine of FIGS. **1** and **2**, gear **86A** remains stationary with respect to cage **82**. Because the helical, driven and driving gears are all mounted in cage **82**, they all rotate with the cage when the cage is driven by the drive belt or other drive means. Helical gears **85A** and **85B** travel around gear **86A** and in turn provide the motive power to turn the gear trains and rotate the pinch rolls.

Thus, it is apparent that the rotation of cage **82** will both twist the yarn about its own axis and produce a rotation of the pinch rolls which will feed the yarn through the device.

Appropriate gear ratios may be chosen to produce a desired overfeed across the second heater — that is, between feed roll **50** and the pinch rolls **81A** and **81B**.

It is, of course, contemplated that any suitable conventional false twist means may be employed as second false twist means **80**.

EXAMPLE

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

The sample was processed from 150 denier 34 filament polyester yarn (Dacron, type 56, merge 19214) on a Leesona 553/570 machine. Machine parameters were set as follows: first spindle speed = 150,000 RPM; primary twist = 62.6 turns per inch, S; primary overfeed = 0 percent; package overfeed = −4.5 percent; first heater temperature = 420°F; second heater temperature = 385° F. The second false twist means was a conventional spindle mounted upsidedown and downstream of the second heater. The second false twist spindle was rotated in a manner to impart 10.75 turns per inch of Z twist to the yarn.

Samples of this 150/34 polyester were taken both with the second false twist spindle in operation and with the second false twist spindle removed. These samples will hereinafter be referred to as "modified set yarn" and "standard set yarn" respectively. Skeins were wound from the yarn sampled and sleeves were knit on the standard Fabric Analysis Knitter with one needle removed to "drop a stitch" and make one wale of the fabric quite visible. The torque angle of the fabric thus knit was measured by determining the angle between the visible wale and the longitudinal axis. The standard Leesona Skein Shrinkage Test; Set Procedure (using a load of 0.00016 grams per denier) was performed on the skeins to determine both "wet" and "dry" values.

FIGS. **5** to **10** are photographs of 150 denier 34 filament polyester yarn and may be used to visually compare standard set yarn and set yarn modified by the present invention. It is noted, however, that the actual yarn pictured in FIGS. **5** to **10** is not the same yarn designated as the above "sample." The yarn pictured in FIGS. **5** to **10** was run on the same 553/570 machine as the above sample but machine parameters were slightly different.

Returning to the discussion of the above sample, certain tests were performed and results are tabulated in the following TABLE.

	Percent					Degrees	
Yarn sample	Overfeed across the second heater	Skein shrinkage, wet	Skein shrinkage, dry	Skein volume, first sample as 100%	Hanging loop torque	Torque angle as knit	Torque angle as dyed
First standard set yarn	16	13	13.6	100	93.5	6	22
Second standard set yarn	20	16.5	17.5	131	92.9	9	22
Modified set yarn	16	16	18	294	99.0	0	15

The first standard set yarn sample and the modified set yarn sample were both processed at a second heater overfeed value of 16 percent. The second standard set yarn sample was processed with a second heater overfeed of 20 percent in an attempt to produce a yarn having percent skein shrinkage values approximately equal to the equivalent values of the modified set yarn.

The skein shrinkage values were determined 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 well 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:

$$\text{Number of wraps} = \frac{12{,}500 \text{ denier}}{\left[\text{denier of sample}\right]\left[2\frac{\text{ends}}{\text{wrap}}\right]}$$

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

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

Attempting to define a stretch or set yarn merely with a percent skein shrinkage value is difficult because other factors have a bearing on yarn type. Generally speaking, a skein shrinkage value of 40 percent or more (Stretch Procedure) would define a stretch yarn. Lighter deniers would have a higher percentage value for a good, acceptable stretch yarn — for example, a good 150 or 200 denier stretch yarn may have a skein shrinkage value of 40 percent using the Stretch Procedure while a good 20 denier stretch yarn may have a value

of about 70 percent. As a general rule, for a given denier, the higher the value, the better the stretch yarn.

In like manner, it is difficult to define a set yarn merely in terms of skein shrinkage (Set Procedure). Much of the commercial set yarn in use today has a skein shrinkage of less than 30 percent and preferably less than 20 percent. Earlier set yarn had somewhat higher values up to the 45 to 50 percent range, all using the Set Procedure.

Reference to the Table shows that the skein shrinkage values of all three samples are below 20 percent.

The volumes of the skeins were determined by actual measurement. For comparative purposes, the first standard set yarn sample skein was assigned a volume of 100 percent and the volume of the second standard set yarn sample skein was then calculated as being 131 percent of the first skein. This relatively minor difference is attributable to the increase in percent skein shrinkage values from the first standard set yarn to the second standard set yarn. The skein of the modified set yarn was also measured and volume was calculated at 294 percent. As is apparent, the volume of the modified set yarn skein was appreciably higher than the volumes of either of the standard set yarn skeins.

Because all of the sample skeins contain the same amount of yarn, the volume of the skein may be considered a measure of the bulk of the yarn in the skein. The term "bulk" is used in the sense of indicating the covering power of the yarn per unit weight of yarn when the yarn is knit into a fabric. An increased "bulk" such as the type visible in FIGS. **5–8** indicates that the covering power properties of the yarn have been increased. It can be seen that the modified set yarn has an appreciably greater bulk than standard set yarn, even when both samples have about the same percent skein shrinkage values. The increase in bulk in the fabric is not necessarily proportional to the increase in the skein.

A visual comparison of the yarn samples of FIGS. **5** and **6** and the yarn skeins of FIGS. **7** and **8** indicates a higher bulk in the modified set yarn than in the standard set yarn. The photographs of FIGS. **5** and **6** were taken with the yarn at the same tension and the greater bulk of the modified set yarn sample is readily apparent from the increased bundle diameter and interfilament spacing in FIG. **6**. The skein in FIG. **8** is also easily seen to be bulkier than the skein in FIG. **7**.

Several columns in the Table list values that relate to the amount of torque present in the yarn samples. One such column is headed "percent Hanging Loop Torque." 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 percent 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 percent hanging loop torque for the two standard set yarn samples are about the same as each other and are relatively low values — about 93 percent. The percent hanging loop torque for the modified set yarn, however, is 99 percent. This high percentage figure indicates a very low torque value for the set yarn modified by the teachings of this invention.

Another value relating to torque level is the torque angle of a knitted sleeve. As previously mentioned, one stitch was dropped when the test sleeves were knit. The torque angle was measured after the fabric was knit and then the fabric was dyed in the laboratory using a dye process involving the application of heat. After dyeing, the torque angle was measured again. In the standard samples, values of 6° and 9° were measured in the sleeves as knit and 22° in both as dyed. The modified sample knit into a sleeve with a 0° torque angle that shifted to 15° when the sleeve was dyed. FIGS. **9** and **10** are illustrative of test sleeves with a dropped stitch. FIG. **9** illustrates a sleeve with a torque angle of about +9°. The wales are on the bias from upper right to lower left and, because the letter Z will incorporate the wale, such a fabric is known as a Z fabric. A negative torque angle would indicate a wale from upper left to lower right and would be evident in an S fabric. It is interesting to note that a Z fabric is knit from a yarn that had an S twist imparted thereto by the first false twist means and vice-versa. FIG. **10** illustrates a sleeve knit from a sample of modified set yarn and it has a torque angle substantially equal to zero.

When the test fabric sleeves were dyed the torque angle exhibited a shift. This is because fabric finishing such as dyeing activates latent torque forces. The Fabric Analysis Knitter knits a sleeve with a Single Jersey stitch and such a sleeve is affected by fabric finishing to a larger degree than a fabric with a more complicated knit such as tricot or double knit. A fabric knit with one of the latter-mentioned knits would not exhibit such a large torque angle shift when finished.

In the present invention, it is believed that the twisting action of the second false twist means cooperates with the action of the heat supplied by the second heater and correlated tension in a manner that may be described as a combination of mechanical 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 zone. The heat supplied by the second heater minimizes the torque by relieving stress in the yarn by annealing and the second twisting mechanically rearranges the filaments of the yarn to reduce the torque yet enhance the bulk.

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 terms such as reducing or diminishing are used with reference to the residual torque, the terms are used in their absolute sense and not in a mathematical 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 diminished when compared with a yarn with a torque angle value of −6°.

Fabric finishing activates latent torque forces. It is therefore sometimes necessary to twist the yarn in the second twisting to a higher negative value than would be expected by examining the yarn or greige fabric when zero torque is desired in the final finished fabric. This processing reverses the torsional forces of the yarn bundle.

FIG. 11 illustrates a graph that is of value in understanding the present invention.

The reduced torque modified set yarn processed according to this invention will have an "F-Factor" value below the curve shown in FIG. 11. The F-Factor is defined by the equation.

$$F = (\text{Tension})/(\text{Denier}) \times (\text{Twist})$$

where the (Tension) is the tension in grams of the yarn strand across the second heater and the (Twist) is the number of twists per inch imparted to the yarn by the second false twist means.

Yarn processed according to the instant invention will, to the best of our knowledge, fall on or below the curve but the converse is not necessarily true. Other yarns not processed by this invention may fall on or below the curve, but they will have unacceptable skein shrinkage values for a set yarn.

As is apparent, the tension may be very low and difficult to measure precisely, especially for higher values of overfeed. In such cases, one may calculate the F-Factor by arbitrarily using a tension value as large as one gram. For example, the F-Factor of a 150 denier yarn must be equal to or below a value of 0.1 and the skein shrinkage value must be acceptable for a set yarn if this 150 denier yarn is to be considered yarn processed by this invention. In this example, values may be substituted in the formula in the following manner:

$$0.1 \geq F = (\text{Tension})\ (\text{Twist})/150$$

In an actual test of 150 denier yarn, the value of the (Twist) was found to be about 10.75 turns/inch. The tension was quite low due to an overfeed of 16 percent and so a value of one gram will be assigned for the tension. Substituting these values into the equation:

$$0.1 \geq F = (1)\ (10.75)/150 = 0.072$$

$$0.1 \geq 0.072$$

Thus, the F-Factor for the 150 denier set yarn would be equal to 0.072 and this value would fall below the curve.

If, for example, a high twist level such as 65 turns per inch was substituted in the equation or a higher tension such as 3 grams was substituted in the equation, the F-Factor would exceed 0.1 and the yarn would not exhibit the qualities of the yarn of the instant invention. Thus, if the 150 denier yarn was highly reverse twisted and/or underfed to create higher tension, the calculated F-Factor would fall above the curve.

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. Apparatus for modifying torque in thermoplastic yarn comprising a first and a second yarn heating zone, a first and a second yarn cooling zone, means for false twisting yarn in the region of said first zones to produce torque stretch yarn, means for overfeeding said torque stretch yarn within a range of from 5 to 25 percent through said second heating zone and said second cooling zone so that crimp deformations are present in the yarn but pigtail deformations caused by torque are not permitted to form, and means to reverse twist said yarn in said second zones to an extent that the twist per unit length is no more than 25 percent of the twist per unit length employed in the torque stretch yarn producing process whereby the torque of the set yarn thus produced is reduced.

2. A method for modifying torque in thermoplastic yarn comprising passing said yarn through a first heating zone and a first cooling zone, false twisting said yarn in the region of said first zones to produce torque stretch yarn, overfeeding said torque stretch yarn within a range of from 5 to 25 percent through a second heating zone and a second cooling zone so that crimp deformations are present in the yarn but pigtail deformations caused by torque are not permitted to form, and reverse twisting said yarn in said second zones to an extent that the twist per unit length is no more than 25 percent of the twist per unit length employed in the torque stretch yarn producing process whereby the torque of the yarn is reduced.

3. A method for modifying torque in thermoplastic yarn comprising passing said yarn through a first heating zone and a first cooling zone, false twisting said yarn in the region of said first zones to produce torque stretch yarn, overfeeding said torque stretch yarn within a range of from 5 to 25 percent through a second heating zone and a second cooling zone so that crimp deformations are present in the yarn but pigtail deformations caused by torque are not permitted to form, and reverse twisting said yarn in said second zones to an extent that the twist per unit length is no more than 25 percent of the twist per unit length employed in the torque stretch yarn producing process whereby the torque of the set yarn thus produced is modified.

4. A yarn with modified torque produced by the method of claim 3.

5. A fabric produced from the yarn of claim 4.

6. A method for producing textured thermoplastic yarn comprising the steps of passing a yarn through a first heated zone, false twisting said yarn in said first heated zone, cooling said yarn and untwisting said yarn whereby a torque stretch yarn is produced exhibiting both crimp deformations and torque induced pigtail deformations if fully relaxed, overfeeding said torque stretch yarn from a fully stretched condition, said overfeeding being with a range of 5 to 25 percent so that said torque stretch yarn passes through a second heated zone with crimp deformations but with torque induced pigtail deformations being prevented from forming, false twisting said yarn in said second heated zone in a direction opposite to the first false twisting and to an extent of not more than 25 percent of the first false twisting, cooling said yarn and untwisting said yarn whereby a set yarn with reduced torque is produced.

7. In a method of making set yarn by the double heater process wherein a thermoplastic yarn is first subjected to a false twisting process to produce a yarn having torque therein which, upon full relaxation of the yarn, causes both crimp deformations and pigtail deformations, said false twisted yarn then being overfed within a range of 5 to 25 percent into the post treating stage so that crimp deformations are present in the yarn but pigtail deformations caused by torque are not permitted to form, said yarn being annealed by heating and subsequent cooling to produce a set yarn having a reduced torque therein which upon relaxation of the yarn causes crimp deformations only, the improvement comprising twisting the yarn being annealed in a reverse direction and to an extent that the twist per unit length is no more than 25 percent of the twist per unit

length employed in the earlier false twisting process to avoid the formation of torque induced pigtails in said reverse direction,and then cooling and untwisting the yarn to produce a set yarn having a torque therein less than said reduced torque.

8. In a method of making set yarn by the double heater process wherein a thermoplastic yarn is first subjected to a false twisting process to produce a yarn having torque therein which, upon full relaxation of the yarn, causes both crimp deformations and pigtail deformations, said false twisted yarn then being overfed within a range of 5 to 25 percent into the post treating stage so that crimp deformations are present in the yarn but pigtail deformations caused by torque are not permitted to form, said yarn being annealed by heating and subsequent cooling to produce a set yarn having a reduced torque therein of a given level which upon relaxation of the yarn causes crimp deformations only, the improvement comprising twisting the yarn being annealed in a reverse direction and to an extent that the twist per unit length is no more than 25 percent of the twist per unit length employed in the earlier false twisting process, and then cooling and untwisting the yarn so that the torque in the yarn will be reduced below said given level but the crimp in the yarn will be retained at least at the level obtained by annealing alone.

9. A yarn produced by the method of claim **8.**

10. A fabric produced from the yarn of claim **9.**

11. The method of claim **8** wherein said reverse twisting and said untwisting is accomplished by false twisting.

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