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R. L. DAHLSTROM ETAL

3,069,836

YARN RELAXATION PROCESS USING FLUID JETS

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FIG. 1

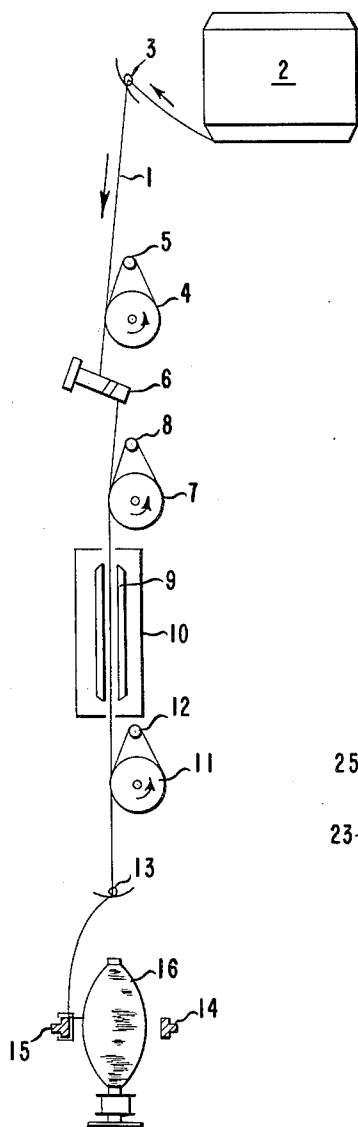


FIG. 5



FIG. 2

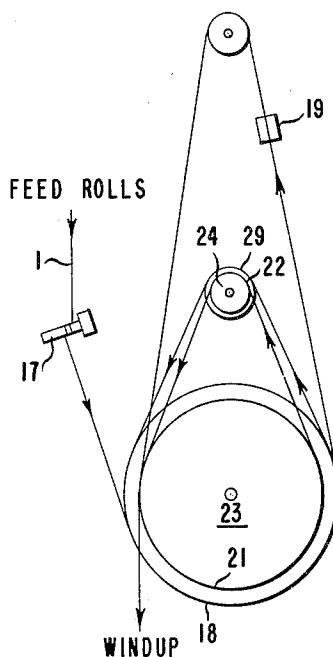


FIG. 3a

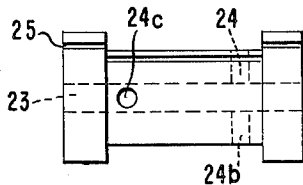


FIG. 3b

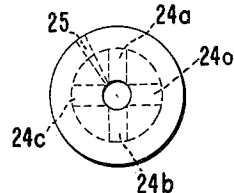
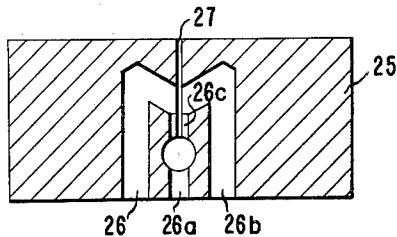


FIG. 4



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YARN RELAXATION PROCESS USING
FLUID JETS

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12 Claims. (Cl. 57—157)

This invention relates to an improved method for effecting the controlled relaxation of yarns composed of synthetic linear polyamides, polyesters, and the like. More specifically, this invention has reference to relaxed interlaced yarns and to their production in a single, continuous operation.

U.S. patent application Serial No. 661,095, filed May 23, 1957, now abandoned and Belgian Patent 567,997 to G. Pitzl, disclose a highly useful process which permits preparation of freshly drawn nylon yarn exhibiting reduced residual ("boil-off") shrinkage achieved with a substantial improvement in intrapackage uniformity of yarn tensile properties. Such improved yarns are prepared by relaxing freshly drawn nylon yarn in a controlled, i.e., metered amount, then winding the yarn onto a package within a specified range of tension. Prior art relaxation or preshrinking procedures, being uncontrolled, invariably have led to yarn showing poorer uniformity of intrapackage yarn properties, relative even to those of the supply yarn. The improved controlled relaxation process is quite attractive commercially, representing the first practical solution to the problem of pirn taper barré, which contributes to the production of fabrics essentially free from streaks, barré, and the like defects.

In yarn packaging processes, the windup usually is either a twister or a reciprocating traverse, the latter being employed when zero-twist yarn subsequently can be utilized. However, the number of applications for zero-twist yarn is definitely limited since such yarn performs rather poorly in many of the common textile operations, owing to a looseness of structure which increases the incidence of broken filaments. By twisting the yarn into a compact structure, such difficulties are usually avoided, but only at the expense of process speed and flexibility. If it were possible to circumvent the twisting operation while still packaging a compact structure free from the potential shortcomings of ordinary zero-twist yarn, the above-described process could be carried out substantially continuously at high speeds with reduced equipment and operator costs.

A primary object of this invention is to provide a relaxed interlaced yarn, i.e., a yarn prepared by controlled relaxation procedures and which, even at zero-twist, has handling characteristics at least the equal of conventional twisted yarn. Another object is to provide such a yarn composed of poly(hexamethylene adipamide). Yet another object is to provide such a yarn which is composed of poly(ethylene terephthalate). Another object is to provide freshly drawn yarns composed of poly(hexamethylene adipamide) which have been continuously relaxed in a controlled amount in excess of about 12%. A still further object of this invention is to provide a warp, tow, package, or fabric made up at least in part of yarns of the foregoing types.

Another object of this invention is to provide a process whereby yarns composed of synthetic linear polyamides, polyesters, and the like are relaxed in a controlled manner and simultaneously interlaced to form a compact unitary strand, both steps being carried out in a single rapid and continuous operation. A further object is to provide such a process whereby the yarn is freshly drawn immediately prior to simultaneous relaxing and interlacing.

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A still further object is a process whereby yarns composed of poly(hexamethylene adipamide) are relaxed in a controlled amount in excess of about 12%. Still another object is a process for relaxing yarn in a continuous controlled manner, the process utilizing hot air at relatively convenient temperatures as the relaxing medium. These and other objects, together with the means for accomplishing them, will appear hereinafter.

The objects of this invention are accomplished by an improved method which comprises forwarding a relaxable filamentary structure composed of synthetic linear polyamides, polyesters, or the like at uniformly positive tension through a zone of fluid turbulence, directing a heated fluid into the zone onto the filamentary structure with sufficient force to separate the filaments of the structure and interlace them into a compact unitary strand, simultaneously permitting the filamentary structure to relax in a controlled, i.e., metered amount, and thereafter winding it into a package at a sufficiently reduced tension that immediate or subsequent elongation of the yarn is substantially avoided. A preferred embodiment, where very low shrinkage is required, e.g., for welt yarns, comprises relaxing, with air at a temperature between about 350° and about 450° C., a freshly-drawn yarn composed of poly(hexamethylene adipamide) in controlled amount in excess of about 12% based on the length of the filaments of the structure, simultaneously interlacing the same, and continuously thereafter winding the yarn onto a package at a tension of from about 0.05 to about 0.15 gram per denier. In another preferred embodiment, such as for weaving yarns, freshly drawn yarn is relaxed in a controlled amount from about 7 to 12%, based on the length of the filaments of the structure, and is thereafter wound up at 0.05–0.35 g.p.d. tension.

There results from this process a relaxed interlaced yarn, i.e., a compact unitary strand maintaining its unity even when the bundle is at zero-twist, and which exhibits substantial reductions in residual shrinkage achieved with substantial improvement in intrapackage uniformity of yarn properties.

The yarn is composed of filamentary structures which are randomly twisted and interentangled throughout the structure. In general, the yarn has a residual shrinkage below about 7% and contains filaments which are sufficiently interentangled to provide the yarn at zero bundle twist with handling properties of a true twist yarn of the same composition and having at least ½ turn per inch twist.

The filaments of the yarn are composed of partially oriented, thermoplastic synthetic polymeric compositions, preferably polyamides and polyesters, such as poly(hexamethylene adipamide) and poly(ethylene terephthalate). Such a product is obtained in a surprisingly rapid and continuous manner, presumably owing to the unexpectedly high rate of heat transfer from the relaxing medium to the yarn, which is particularly apparent in the use of a fluid jet apparatus.

The invention is applicable to yarns, filaments, and similar strands whether spun or continuous; continuous multifilament yarn, shortened to "yarn," will be employed hereinafter as exemplary of all such strands, since in this form the invention has its greatest utility.

FIGURE 1 shows schematically an apparatus assembly useful in the practice of the prior art.

FIGURE 2 shows schematically an improved and preferred arrangement of apparatus for accomplishing the process of this invention.

FIGURES 3a, 3b and 4 show various fluid jets which are useful in the practice of the present invention.

FIGURE 5 illustrates a relaxed interlaced yarn.

Referring to FIGURE 1, an undrawn yarn 1 is withdrawn from package 2, passed through pigtail guide 3,

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and then passed in multiple wraps about driven feed roll 4 and associated separator roll 5. From feed roll 4, the undrawn yarn 1 passes in several wraps about snubbing pin 6, as taught by Babcock in U.S. Patent 2,289,232. The yarn is drawn in frictional contact with pin 6 under the urging of draw roll 7 and its associated separator roll 8. Draw roll 7, of course, has a higher peripheral speed than feed roll 4, whereby the yarn is elongated to several times its original length. From draw roll 7, the yarn passes through relaxing means, in this case oven 9 with jacket 10 (heating means not shown), to relaxing roll 11 and its separator roll 12. The relaxation permitted the yarn is controlled by adjusting the relative peripheral speeds of rolls 11 and 7. The yarn next passes through pigtail guide 13 and is wound onto a tapered twister package 16 by means of ring 14 and associated traveler 15. The tension in the yarn wound to package 16 is controlled by the weight of traveler 15, as is well known in the art.

Referring now to FIGURE 2, an undrawn yarn 1 is forwarded by suitable advancing means (not shown, see FIG. 1) to a non-rotating snubbing pin 17 (Babcock U.S. 2,289,232), makes one or more wraps thereabout, being drawn in frictional contact therewith under the urging of draw roll 18 with its associated separator roll 19. The yarn then passes from draw roll 18, traverses fluid jet 19, changes direction over idler roll 20, and passes in multiple wraps around the relaxing roll 21 and its associated separator roll 22, following which the yarn is lead to a windup (not shown, see e.g. FIG. 1) and is packaged in conventional manner. The controlled relaxation of this invention is achieved by the peripheral speeds of the draw roll 18 and relaxing roll 21 components of the stepped roll 23 (similarly, portions 19 and 22 of the stepped separator roll 24) differing in proportion to their diameters; the yarn is thereby relaxed to an extent proportional to the ratio of diameters of the drawing and relaxing rolls. Relaxation is initiated by the action of heated fluid being supplied to the yarn in fluid jet 19, wherein interlacing of the yarn components simultaneously takes place. The feed yarn 1 may be supplied from a package or a spinning machine; the drawing and relaxing steps need not be carried out sequentially. The illustrated embodiment is a most compact and economical apparatus arrangement for accomplishing relaxing and interlacing in accordance with this invention.

FIGURES 3a and 3b show a fluid jet preferred for use in the present invention. Fluid jet 2 has a lengthwise yarn passageway 23 which, in this embodiment, is substantially cylindrical in form throughout its length. Fluid conduits 24a, 24b, 24c, 24d intercept on passageway 23 at right angles to the wall thereof and are positioned so that the longitudinal axis of each fluid conduit and yarn passageway 23 intercept perpendicularly. Fluid conduits 24a and 24b and 24c and 24d are arranged as opposed pairs spaced longitudinally along the yarn passageway with their respective longitudinal axes perpendicular. Fluid jet 2 also has lengthwise slot 28 to facilitate stringing-up operations. Optionally, all of fluid jet 2 may be enclosed in a concentric cylindrical jacket, suitably tapped, to provide manifolding of the heated relaxing fluid to each of the fluid conduits.

FIGURE 4 shows another useful fluid jet which contains a lengthwise cylindrical yarn passageway 25 perpendicularly intercepted by a single pair of opposed fluid passageways 26a and 26c, the latter being supplied by fluid ducts 26 and 26b. In addition to supplying fluid conduit 26c, fluid ducts 26 and 26b serve to create a fluid curtain in stringup slot 27. The "fluid curtain" facilitates yarn stringup and, at the same time, prevents the yarn from blowing out of yarn passageway 25. Obviously, numerous modifications in the design of the fluid jet may be made. Many other suitable fluid jets are shown in U.S. application Serial No. 752,451, filed August 1, 1958, now abandoned, to W. W. Bunting and T. L. Nelson. Another

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suitable fluid jet is shown in FIGURE 10 of U.S. Patent No. 2,852,906 to A. L. Breen.

In operation, the fluid jet is positioned intermediate suitable yarn forwarding means, i.e., means capable of advancing the yarn through the fluid jet at uniformly positive tension, such as the apparatus shown in FIGURES 1 and 2. The fluid jet is continuously supplied with heated fluid under pressure, which fluid is directed into the yarn passageway through the fluid conduits. The heated fluid on entering the yarn passageway creates a zone of fluid turbulence which causes the yarn bundle to be opened, i.e., the filaments separated, and simultaneously causes the individual filaments to be twisted and intermingled in a purely random manner to produce a compact interlaced yarn.

Such an interlaced yarn is shown in FIGURE 5 and is a very stable consolidated structure which performs and handles in the same manner as a true-twist yarn. In addition to being interlaced, the individual filaments in the yarn are rapidly and uniformly heated by the impinging fluid while the bundle is "opened." The surprisingly efficient and uniform transfer of heat to the individual filaments in the yarn bundle causes the yarn to relax readily, in an amount depending on the relative forwarding and advancing speeds. The unexpectedly high rate of transfer of heat from the heated fluid, i.e., the relaxing medium to the yarn makes possible controlled relaxations in amounts heretofore unattainable, and results in yarns having greatly reduced residual shrinkage achieved with excellent uniformity of properties, in addition to being interlaced. Moreover, owing to such efficiency of heat transfer, relaxing fluids at much lower temperatures than normally employed may be utilized.

Among the important variables which affect the process of this invention are the pressure of the relaxing fluid and the yarn tension in the relaxing zone, which affect the density of interlacing; the temperature of the relaxing fluid, and the yarn denier and speed which affect the extent of controlled relaxation. These various factors are described in considerable detail in the above-mentioned Bunting and Nelson application and in the Pitzl application, which relate to interlacing and controlled relaxing, respectively. Insofar as product uniformity and the effective amount of relaxation, which ultimately affects the extent of reduction of residual shrinkage, is concerned, the yarn tension at the windup appears controlling. For this reason, it is preferred that the windup tension be between about 0.05 and about 0.35 gram per denier, preferably less than about 0.25 gram per denier, tending progressively toward the lower value as the extent of controlled relaxation is increased. Otherwise, if the yarn tension is too high at the windup, some "redrawing" may occur, i.e., some of the percentwise relaxation is lost due to attenuation or elongation of the yarn under the influence of excessive windup tension. In this connection, it has been observed that a winding tension of about 2 grams absolute represents the least tension which can be used in a practical process. It is essential to maintain winding tension high enough to prevent sloughing of the package during shipment, but low enough to prevent objectionable "redrawing" of the yarn.

The density of interlacing is directly proportional to the pressure of the relaxing fluid, as supplied to the fluid jet. The amount of controlled relaxation also depends, in part, on the pressure of the relaxing fluid, which, together with tension, determines the extent of yarn bundle "opening."

Any fluid reasonably inert to the yarn may be employed as the relaxing agent, with hot air being preferred in many applications. The fluid may be a liquid or gas at the temperature of operation, but inert gaseous material such as steam, nitrogen, carbon dioxide, etc., are preferred. For best results, the interlacing fluid should reach a velocity of about $\frac{1}{2}$ sonic velocity or more, immediately prior to impinging upon the yarn. At higher

velocities, less dense fluids may be employed. For the present purposes, heated air at pressures between about 10 p.s.i.g. and about 100 p.s.i.g. are desirable, with pressures between about 15 p.s.i.g. and about 30 p.s.i.g. being preferred. To achieve a desired amount of controlled relaxation, the temperature of the air is inversely related to the pressure, i.e., the higher the temperature, the lower the pressure required. The temperature of the fluid should not be so high as to be deleterious to the yarn, e.g., cause fusion or degradation of the filaments, nor should it be so low that insufficient relaxation results, leading to slackness in the yarn line. Of course, fluid pressure requirements and hence fluid consumption are related to the dimensions of the fluid jet.

For example, at a pressure of about 15 to about 30 p.s.i.g., temperatures between about 200 and about 500° C. are suitable. The temperature of the fluid should not be so high as to be deleterious to the yarn, e.g., cause fusion or degradation of the filaments, of course, fluid pressure requirements and hence fluid consumption are related to the dimensions of the fluid jet.

Proper control of yarn tension in the vicinity of the fluid jet also is an important factor affecting interlacing density, which varies inversely with the yarn tension. The yarn tension should be uniformly positive in the relaxing zone, i.e., should be maintained at a constant value exceeding that tension which derives from the weight of the yarn per se, sufficiently high to avoid looping, curling, or crimping of the yarn. It is characteristic as well as necessary in a controlled relaxation that the yarn line never becomes "slack." To further uniformize yarn tension in the relaxing zone, inline fluid jets, such as those shown in FIGURES 2-4, are preferred, since such jets offer no snubbing surfaces nor divert the yarn path. In controlled relaxations, especially in amounts in excess of about 12%, this yarn tension is normally self-seeking, running at uniform values between 1 and 2 grams in the steady state. These values are sufficiently low to permit interlacing of quite ample density. Although satisfactory interlacing can be attained at higher tensions, tensions exceeding about 5 grams rarely occur during controlled relaxations. The effects of excessive tension can always be overcome by an increase in the pressure of the relaxing fluid. Finally, the density of interlacing appears to be insensitive of yarn speed.

Although steam is an efficacious relaxing agent, hot air is usually preferred for its availability and lack of condensation in its use. Hot air at temperatures in excess of about 180° C. is capable of producing controlled relaxations of about 12% or more in 66-nylon. Since relaxation apparently is accelerated by moisture, the yarn can be wet with water, a solution of a swelling agent (V. Miles, U.S. 2,157,119), or the like prior to relaxation with hot air in the fluid jet. Optionally, the yarn may be preheated prior to encountering the fluid jet, e.g., using an oven, such as shown in FIGURE 1. Of course, the temperature of the relaxing agent is limited somewhat by the stability characteristics of the polymer from which the yarn has been prepared. The yarn speed determines the extent of relaxation at any given temperature of the relaxing medium, since at increasing speeds, the time of exposure of the yarn to the relaxing fluid is decreased. For example, at 100 yards per minute the yarn remains in a ½-inch jet for about 0.01 second; at 500 yards per minute, the exposure time is reduced to less than 0.002 second. Multiple fluid jets may be employed in instances where it is desirable to increase exposure times without decreasing yarn speeds. The temperature of the relaxing medium should be increased and/or the yarn speed decreased for higher denier yarns, in order to compensate for the greater mass of such filaments.

The following examples illustrate specific embodiments of this invention.

EXAMPLE I

Poly(hexamethylene adipamide) yarn of 34 filaments and spun denier of 208 (23 tex) is drawn to a final denier of about 70 (7.6 tex) using the prior art apparatus substantially as shown in FIGURE 1. Immediately after drawing, the yarn is subjected to a series of relaxation treatments, using the same apparatus. The yarn is relaxed in relaxing means 9, which in the present experiment is an oven, 12 inches in length. The yarn speed in the oven is 562 yards per minute, hence the exposure time in the oven is about 0.03 second. The windup tension throughout this series of tests is maintained at 0.17 gram per denier (g.p.d.). Table I shows the improvement in yarn shrinkage and shrinkage uniformity under various conditions of relaxation.

Table I

Test	Percent relaxation	Medium and temp.	Percent shrinkage	
			Avg. ¹	Range ²
AA-----	None	-----	9.1	1.7
AB-----	(3)	Steam, 100° C.-----	7.5	2.0
AC-----	8 0	do.-----	7.2	0.9
AD-----	12 0	do.-----	(4)	(4)
AE-----	12 0	Superheated steam, 175° C.-----	4.3	-----
AF-----	12 0	Air, 500-600° C.-----	4.4	-----

¹ Average residual shrinkage of the yarn.

² Maximum difference in residual shrinkage between samples taken from the same bobbin.

³ Uncontrolled.

⁴ Inoperable.

⁵ Yarn windup tension is 0.05 g.p.d. in these two tests.

After treating the yarn samples under the conditions shown in Table I, packages of each sample are maintained for 7 days at 75° F., 72% relative humidity prior to testing. The yarn samples are obtained by stripping yarn from the package, taking representative samples of 130 to 150 cm. in length. The samples are taken from the extremities of the package and from the longitudinal center of the package, throughout the entire package.

Sample length is determined immediately after removal from the package; the ends of the yarn segment are knotted together, a weight of about 0.1 g.p.d. is hung in the loop, and the length of this loop measured. After determining the initial length, the loop of yarn is submerged in boiling water for about 20 minutes, after which it is removed and dried about 25 minutes under the 0.1 g.p.d. tension. The length of the boiled-off loop is measured and the percent shrinkage is calculated based on the length of the original sample.

Test AA shows typical values for what amounts to a conventional drawing process, without provision for relaxation and without use of the heating oven. The average residual shrinkage level of yarn processes under these conditions is 9.1%, with an average residual shrinkage range of 1.7% through the bobbin. Under the conditions of test AA, of course, the yarn by-passes rolls 11, 12.

Test AB represents the same conditions as test AA, except that steam at 100° C. is introduced into oven 9. The yarn is thus permitted to relax as much as possible under the established winding tension of 0.17 g.p.d., but the amount of relaxation is not controlled by means of rolls 11, 12. Under these conditions, the average shrinkage is 7.5%, but there is an even greater shrinkage spread (2.0%) than was the case with conventional drawing (test AA). This result is typical of those obtained by prior art uncontrolled relaxation procedures.

Test AC shows the advantages obtained with a controlled amount of relaxation, initiated in this case by the 100° C. steam in oven 9. The reduction in residual shrinkage is comparable to that attained in test AB; however, unlike the latter test, the shrinkage range is decidedly improved in test AC. In test AD, the upper

limit of relaxation under the present test conditions has been exceeded, as evidenced by the deterioration of threadline stability to the point of inoperability, where severe backwrapping on the relaxing rolls 11 and 12 causes the yarn line to break down.

In test AE, by increasing the steam temperature, the yarn can be relaxed in a controlled amount of 12%. This figure represents about the practical upper limit of relaxation using ovens, steam tubes, or the like.

In test AF, no steam is admitted to oven 9; the oven is heated by means of electrical heaters embedded in the jacket 10. The yarn is thus subjected to radiant heat from the walls of the oven. A thermocouple placed within the oven, prior to introduction of the yarn, registers an air temperature of 500–600° C. This test illustrates the striking difference between the efficacy of steam and hot air as relaxing media in ovens, hot tubes, and the like apparatus.

Fabrics woven from the yarns of tests AA and AB show a severe streakiness and pirn taper barré. Fabric woven from the yarn of test AC is much improved in this regard, and the fabrics from the yarns of tests AE and AF are excellent.

EXAMPLE II

Poly(hexamethylene adipamide) yarn of 13 filaments is drawn to a final denier of 40 (4.4 tex) using the apparatus of FIGURE 1 modified by the fluid jet shown in FIGURE 3 for the prior art oven shown in the apparatus of FIGURE 1 and by the addition of the preferred stepped draw roll assembly shown in FIGURE 2. Relaxation is effected by using the fluid jet shown in FIGURE 3, which jet is ½ inch in length and is interrupted ⅓ of an inch from each end by 2 pairs of opposed (180°) fluid conduits, the separate pairs having their common longitudinal axis at right angles, each with respect to the other. The diameter of the yarn passageway is 0.052 inch; each of the fluid conduits is 0.025 inch in diameter. The relaxing agent is supplied to each of the fluid conduits at about the same temperature and pressure. The results of a series of relaxations using hot air and superheated steam at 316° C. and 18 p.s.i.g. pressure are shown in Table II. The yarn speed during the relaxation step is 560 y.p.m., hence the time of exposure (yarn in the jet) is less than about 0.0015 second. Tension at the windup is about 4 grams, and is about 1–2 grams in the relaxing zone.

Table II

Test	Percent relaxation	Percent shrinkage ³		Interlaces/inch ¹	
		Air ²	Steam	Air	Steam
BA-----	13.5	2.9 (2.8)	3.0	1.7	1.3
BB-----	15	2.7	3.4	2.1	1.7
BC-----	16.5	2.2 (1.5)	2.7	2.1	1.7
BD-----	18	2.3 (1.3)	2.7	2.1	1.7
BE-----	20	2.3 (1.2)	2.5	2.1	1.7

¹ Determined as in Example I.

² Determined by weighted (1.5 gram) hook; the method is described in U.S. application S.N. 752,451 filed Aug. 1, 1958.

³ Parenthetical values refer to runs using 360° C., 40 p.s.i.g. air.

The results in Table II show the outstanding improvements characteristic of this invention. Operability in all cases is satisfactory, with test BC considered to be the optimum balance of both yarn properties and operability. Quite unexpectedly, hot air appears to be somewhat more efficacious as a relaxing medium than steam. The high levels of controlled relaxation evidenced in tests BA through BE are quite surprising considering the abbreviated exposure times, ca. 20 times less than those of Example I. The results seen particularly in tests BC–BE are characteristic of controlled relaxation, i.e., progressively less additional reduction in residual shrinkage is attained by increasing the amount of relaxation as the upper limit of relaxation is approached. These results

differ from prior art procedures involving preshrinkage, setting, and various other phenomena; in such cases residual shrinkage usually is linearly related to the amount of lengthwise retraction, reductions therein being achieved without appreciable improvement in differential shrinkage properties. By using higher temperatures (particularly) and/or pressures, the residual shrinkage of the yarn can be further reduced. This is shown by the parenthetical entries under "Air" in Table II.

All of the yarns produced in this example are interlaced. The density of interlacing is about same within the two series; this behavior is expected since the yarn tension remains about the same throughout these tests, yarn tension being a prime interlacing variable. Similar results are obtained in this example when the polyamide is poly(ϵ -caproamide).

Other fluid jets also are suitable for use in the process of this invention, as will be exemplified. The jet of FIGURE 10 of U.S. 2,852,906 is used to relax the yarn of this example with 200° C. air at 30 p.s.i.g. pressure to obtain the Table IIA results.

Table IIA

Test	Percent relaxation	Percent shrinkage
BF-----	13	3.3
BG-----	16.5	3.2

EXAMPLE III

Using the fluid jet of FIGURE 4 in the apparatus of Example II, 17-filament yarn composed of poly(ethylene terephthalate) is drawn to a denier of about 35 (3.8 tex), then relaxed in a controlled amount. The fluid jet is ¼ inch long, has a 0.050-inch diameter yarn passageway, and a pair of opposed (180°) 0.025-inch diameter fluid conduits. The drawing apparatus is modified so as to include heated plates rather than a draw pin in contact with the yarn in the drawing zone, in order to draw the yarn. Air pressure is 70 p.s.i.g. through this series of tests. The results of these tests are shown in Table III.

Table III

Test	Percent relaxation	Draw ratio	Hot plate temp., °C.	Air temp., °C.	Percent shrinkage
CA-----	15	3.5	84	340	3.2
CB-----	15	3.15	100	320	2.2
CC-----	17	3.15	100	320	2.0
CD-----	23	3.15	100	320	1.6

EXAMPLE IV

The procedure of Example II is repeated in order to examine the effects of temperature and pressure in the operation of this invention. The results are reported in Table IV.

Table IV

Test	Pressure series ¹		Test	Temperature series ²	
	Pressure, p.s.i.g.	Percent shrinkage		Temp., °C.	Percent shrinkage
DA-----	30	4.9	DG-----	195	4.3
DB-----	40	3.7	DH-----	215	3.8
DC-----	50	3.1	DI-----	235	3.2
DD-----	60	2.9	DJ-----	270	2.3
DE-----	70	2.5	DK-----	335	1.6
DF-----	100	2.2			

¹ 40–13 poly(hexamethylene adipamide) yarn, 16.5% relaxation, 212±6° C.

² 40–13 poly(hexamethylene adipamide) yarn, 16.5% relaxation, 40 p.s.i.g.

These results show that for any given amount of relaxation the percent-wise residual shrinkage decreases as the temperature or pressure of the relaxation medium is in-

creased. The density of interlacing throughout the temperature series remained substantially constant; interlacing density is seen to increase with increasing pressure.

EXAMPLE V

The apparatus assembly of Example II is used to examine the effects of varying draw ratio, yarn denier, yarn count, and yarn speed on residual shrinkage of poly(hexamethylene adipamide) yarns. The test yarns are relaxed 13.5% with 220° C. air; the air flow is 0.95 s.c.f.m. The yarn speed is 790 y.p.m. (ca. 0.001 second exposure in the jet).

Table V

Test	Count	Draw ratio	Drawn denier	Percent shrinkage
EA-----	13 fils-----	2.99	43.6	4.2
EB-----	do-----	3.08	42.2	4.1
EC-----	do-----	3.17	41.0	3.9
ED-----	do-----	3.27	39.9	3.7
EE-----	34 fils-----	2.74	76.7	6.0
EF-----	do-----	2.82	74.5	5.9
EG-----	do-----	2.91	72.4	5.8
EH-----	do-----	2.99	70.2	5.8

Runs EA to ED are repeated at 563 y.p.m.

EL-----	13 fils-----	2.99	44.6	3.8
EJ-----	do-----	3.08	43.2	3.5
EK-----	do-----	3.17	42.0	3.3
EL-----	do-----	3.27	40.6	3.3

The results show that the drawing speed has an appreciable affect on the ultimate level of residual shrinkage (compare test series EA-ED and EI-EL), the effective amount of relaxation depends inversely on yarn denier (compare tests EA and EH), and, for the lower denier yarn, the effective amount of relaxation depends directly on the draw ratio (test series EA-ED and EI-EL). In each series of tests, the density of interlacing is about the same.

EXAMPLE VI

Supplementing Example IV, the apparatus assembly of that example is utilized to prepare at various air temperatures and pressure 40 denier (4.4 tex) 13 filament yarns of poly(hexamethylene adipamide) having predetermined amounts of residual shrinkage. The results are recorded in Table VI.

Table VI

Run	2% residual shrinkage		Run	1.8% residual shrinkage	
	Temp., ° C.	Pressure p.s.i.g.		Temp., ° C.	Pressure p.s.i.g.
FA-----	325	30	FE-----	360	30
FB-----	355	25	FF-----	400	25
FC-----	400	20	FG-----	440	20
FD-----	440	15	FH-----	485	15

These data show that desired levels of residual shrinkage can be achieved at various temperature-pressure combinations. The higher the air temperature, the lower the pressure required to produce a yarn having a given value of residual shrinkage. Often, for the present purposes, it is preferred to employ high temperature fluids at reduced pressure, thereby decreasing the consumption of such fluids. In Examples II-VI the yarn is packaged at a spindle-type windup primarily to provide low tension during packaging. The amount of twist imparted in all cases is low, since the yarns are interlaced and hence do not require twist.

Fluid jets most useful in the practice of this invention are those of the interlacing variety shown in detail in the above-mentioned patent application to Bunting and Nelson. Texturing jets, such as those shown in U.S. 2,852,906 to Breen are nearly as effective, especially the jet shown in FIGURE 10 of that patent. In certain appli-

cations the torque jets shown in Belgian Patent 567,586 to Breen and Sussman, can be useful, since yarn bundle "opening" is believed to attend their operation, although such "opening" or filament separation does not occur to as great an extent as in the above-described interlacing and texturing jets. The product of the torque jet would be either relaxed zero-twist yarn or, provided the rate of twisting is suitably varied, a relaxed stable alternating twist yarn. In general, the apparatus which are useful as relaxing means in this invention are those in which high-velocity fluid can encounter a running yarn in a confined region or passageway, preferably in a near-perpendicular direction. Optimum relaxing and interlacing is achieved when the yarn is acted upon by zone of controlled fluid turbulence formed by a plurality of fluid vortices, the axes of which are substantially parallel to the axis of the running yarns at the time of contact.

Winding tensions satisfactory for the process of this invention are between about 0.06 to about 0.35 g.p.d., with a preferred range of from 0.1 to 0.25 g.p.d. In controlled relaxations greater than about 12%, the windup tension preferably is less than about 0.15 g.p.d. for decreased residual shrinkage. Such tensions are conveniently obtained by use of the proper size traveler on the twister ring, considering also the denier of the yarn being wound, as is well known to those skilled in the art. In this connection, it has been observed that a winding tension of about 2 grams absolute represents the least tension which can be used in a practical process for winding low-denier yarns. Alternatively, suitable tension devices may be used for other types of traversing and winding mechanisms. It is essential to maintain winding tension high enough to prevent sloughing of the package during shipment, but low enough to prevent objectionable retensioning of the yarn. In general, under otherwise the same processing conditions, lower levels of yarn tension permit a proportionately greater improvement in residual shrinkage and shrinkage uniformity, both being achieved with improved operability up to the upper limits of relaxation of this invention.

Since the product of this invention is an interlaced yarn, it need not be packaged at twisting windup, since an interlaced yarn already has the handling and take-off characteristics of a twisted structure. In addition, it is advantageous to use the process of this invention in winding square- or tapered-shouldered packages upon cylindrical bobbins using conventional reciprocating traverses (in which no twist is inserted), thereby decreasing shrinkage differences between yarn on the inside and the outside of such packages. This improvement is obtained by applying a suitable tension to the yarn prior to winding. This invention makes it possible to wind freshly drawn polyamide yarn on paper (cardboard) cores, thus providing a single-use or "one-way" shipping package in one operation. On the other hand at high relaxations it is often preferred to use a ring-traveler windup because of the low and uniform tension at which the yarn is wound onto the package. Similarly, the use of the "filling wind" permits similar uniformity of yarn take-off tension.

The yarn counts for which this invention is useful may range from monofilament yarns to any desired number of filaments; for heavy denier yarns, it may sometimes be necessary to increase the heating time or temperature in the fluid jet to compensate for the greater mass of the filament bundle. In particular, the upper limit of relaxation has been observed to depend on the denier of the yarn being relaxed and on the extent to which it has been drawn. After relaxing with extremely hot air it may be desirable in some cases to treat the yarn with moisture, preferably prior to packaging, in order to permit the yarn to regain its normal moisture content.

The process of this invention is especially useful for synthetic linear polyamides; by synthetic linear polyamides is meant those disclosed, for example, by Carothers in U.S. Patents 2,071,250 and 2,071,253. The prep-

aration and spinning of such polyamides is disclosed in U.S. Patents 2,130,948; 2,163,636; and 2,477,156. Examples of such polyamides are those prepared from suitable diamines and suitable dicarboxylic acids, such as hexamethylene diamine and adipic acid. Similarly, polyamides from omega aminocarboxylic acids or their amide-forming derivatives, e.g., polyamide from caprolactam, are included. Additional suitable polymeric compositions include polyesters, such as poly(ethylene terephthalate) and poly(trans-p-hexahydroxylylene terephthalate) or copolymers thereof as in the copolymer of the terephthalate with the isophthalate; vinyl polymers, such as poly(vinyl chloride), poly(vinylidene chloride), or copolymers thereof; polyhydrocarbons, such as polyethylene and polypropylene and any other relaxable polymer.

The process of this invention can be used to relax and interlace staple or continuous filament yarns. The elements of the process may be varied to produce slub yarns, variable denier yarns, thick and thin yarns, and yarns with varying interlacing density. This process can also be combined with a setting step as taught in Belgian Patent 567,997 to Pitzl.

The relaxed interlaced yarn of this invention is useful in all applications which require a twisted yarn, i.e., those in which the handling and running characteristics of nominal zero-twist yarn are not always satisfactory. Such an interlaced yarn can be prepared rapidly and continuously, and is stable, the interlaced structure not being removed by application of normal tension. Use of the yarns prepared in accordance with this invention results in woven and knit fabrics of excellent uniformity and freedom from barré. Yarns prepared via high-temperature steam are deeper dyeing as well as more uniform. Numerous other advantages inherent in the practice of this invention will be readily apparent to those undertaking its practice.

We claim:

1. An improved process for forming an untwisted compact yarn having a sufficiently low residual shrinkage to be wound and stored on light cardboard cores, which comprises forwarding a relaxable synthetic polymeric multi-filament yarn structure at a uniform positive tension through an substantially enclosed yarn interlacing and relaxing zone, directing a stream of heated fluid into said zone with sufficient force and velocity to separate the elements of the structure for maximum heat transfer to said elements and interlace them into a unitary structure while simultaneously permitting said elements to relax in a controlled amount to form a stable compact strand with substantially zero bundle twist characteristics existing uniformly throughout its length, and then winding said structure into a package at a sufficiently low tension that substantial elongation is avoided.

2. The improved process of claim 1 wherein the structure comprises a synthetic polymeric composition selected from the group consisting of polyamides and polyesters.

3. The improved process of claim 1 wherein the heated fluid is at a temperature of at least about 150° C.

4. The improved process of claim 1 wherein the amount of relaxation is in excess of about 7%, based on any unit length of a filament before forwarding to the interlacing and relaxing zone.

5. The improved process of claim 4 wherein the winding tension is between about 0.05 and about 0.35 g.p.d.

6. The improved process of claim 5 wherein the amount of relaxation is in excess of about 12% and the winding tension is between about 0.05 and about 0.15.

7. The improved process of claim 5 wherein the amount of relaxation is between about 7% and about 12%.

8. An improved process for producing an untwisted compact yarn having a sufficiently low residual shrinkage to be wound and stored on light cardboard cores and a low incidence of filament breakage during processing treatments which comprises forwarding a relaxable multi-filament yarn structure of a polymeric composition selected from the group consisting of polyamides and polyesters, at a uniform positive tension, through a substantially enclosed yarn interlacing and relaxing zone, directing a stream of fluid heated to a temperature of at least about 150° C. into said zone at sufficient pressure and velocity to cause turbulence sufficient to separate the filaments of the structure for maximum transfer of heat from the fluid to the filaments and interlace them into a unitary structure, while simultaneously permitting the filaments of the structure to relax in a controlled amount in excess of about 7%, based on the length of the filaments of the structure to form a stable compact strand with substantially zero bundle twist characteristics existing uniformly throughout its length, and then winding the yarn into a package at a tension between about 0.05 and about 0.35.

9. The improved process of claim 8 wherein the fluid is at a pressure between about 10 and about 100 p.s.i.g.

10. The improved process of claim 9 wherein the fluid is air, heated to a temperature between about 200° C. and about 500° C.

11. The improved process of claim 10 wherein the air is at a pressure between about 15 and about 30 p.s.i.g.

12. The improved process of claim 11 wherein the amount of relaxation is in excess of 12%.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,069,836

December 25, 1962

Richard Lee Dahlstrom et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the sheet of drawings, FIG. 3a, strike out the reference numeral "23"; same FIG. 3a, for the reference numeral "24" read -- 24a --; FIG. 4, strike out the reference numeral "25"; column 3, line 24, after "roll" insert -- portion --; same line 24, for "19" read -- 29 --; line 26, after "over" insert -- an --; same line 26, after "roll" strike out "20"; line 28, after "roll" insert -- portion --; line 33, for "19" read -- 29 --; line 47, for "invention. Fluid" read -- invention. The fluid --; same line, strike out "2"; line 48, strike out "23"; line 50, after "on" insert -- the lengthwise yarn --; same line, strike out "23"; line 53, strike out "23"; line 56, for "perpendicular. Fluid" read -- perpendicular. The fluid --; same line 56, strike out "2"; line 57, for "28" read -- 25 --; line 58, before "fluid" insert -- the --; same line 58, strike out "2"; lines 63 and 71, strike out "25", each occurrence.

Signed and sealed this 17th day of September 1963.

SEAL)
Attest:

ERNEST W. SWIDER

Attesting Officer

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Commissioner of Patents