

June 24, 1969

J. D. GEERDES ETAL

3,452,131

PROCESS FOR STRETCHING FILAMENTS

Filed June 27, 1967

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FIG. 1

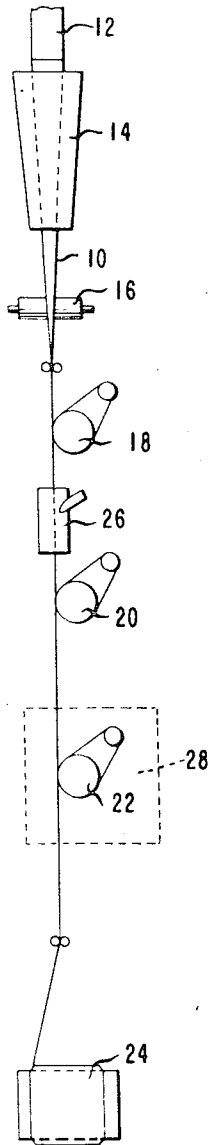


FIG. 2

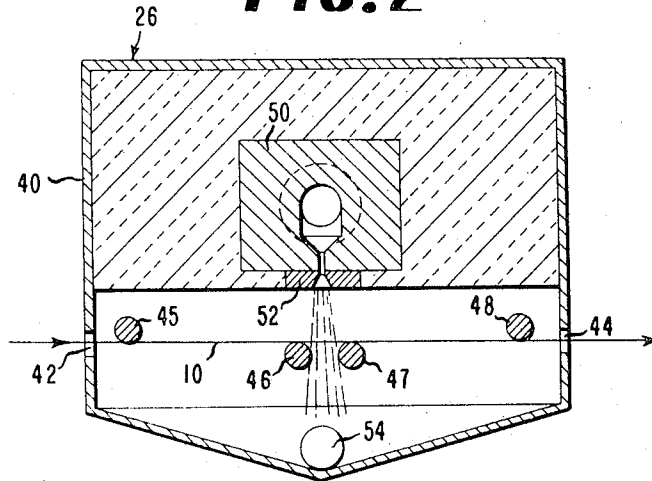


FIG. 3

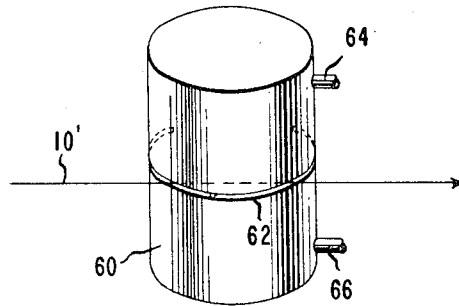
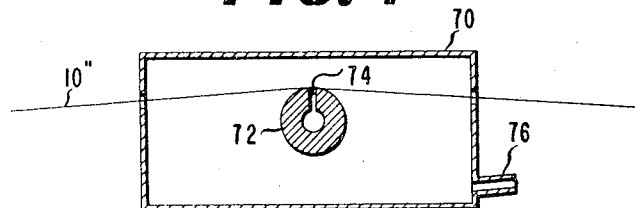


FIG. 4



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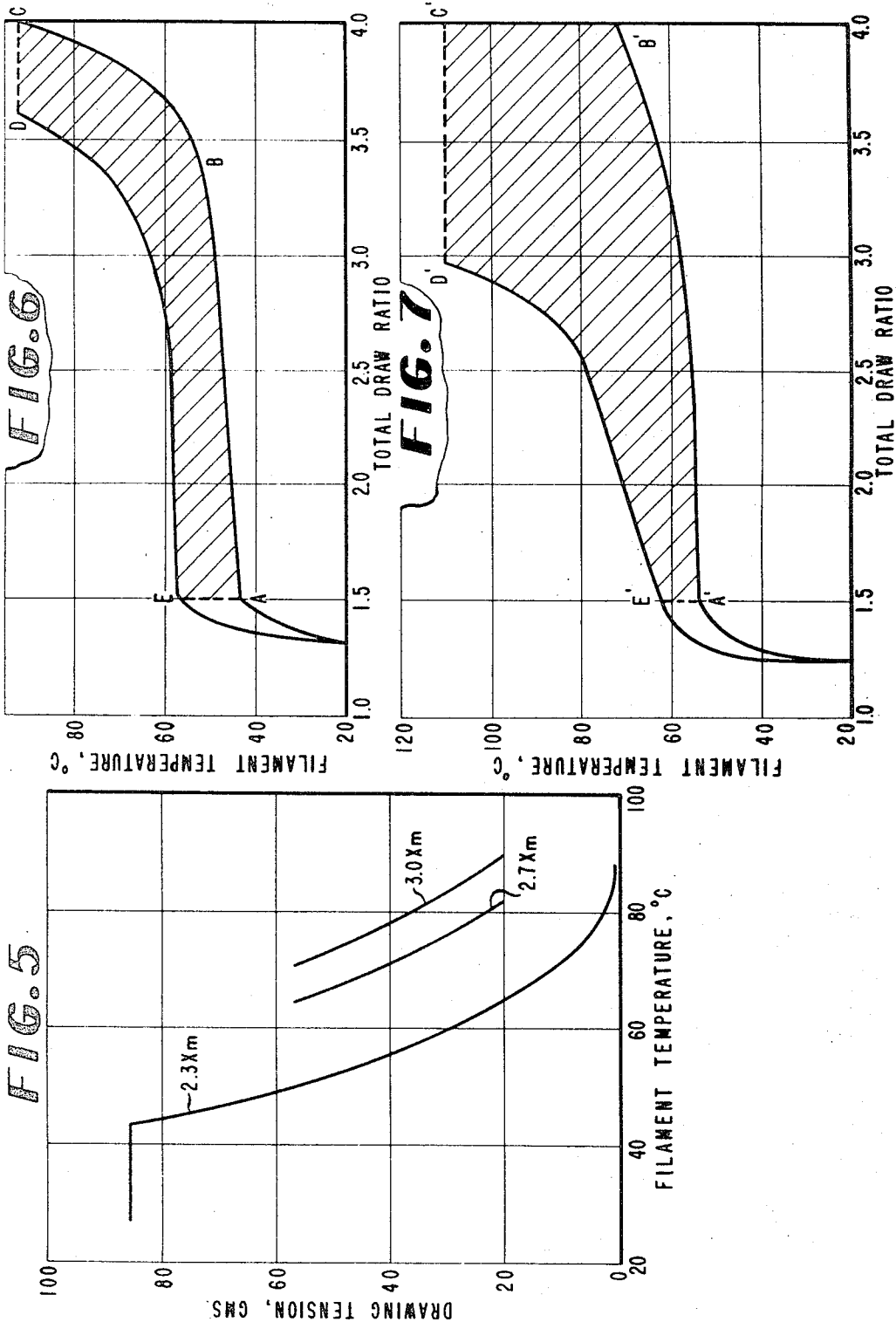
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PROCESS FOR STRETCHING FILAMENTS

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Continuation-in-part of application Ser. No. 536,795, Mar. 23, 1966. This application June 27, 1967, Ser. No. 649,257

Int. Cl. D01d 9/08, 5/12; D02j 1/22

U.S. Cl. 264—210

4 Claims

ABSTRACT OF THE DISCLOSURE

A coupled process for the spinning and two-stage drawing of filamentary nylon yarn, in which the first stage draw point is substantially localized by heating the yarn substantially instantaneously, in a fluid jet, to a filament temperature of at least 44° C.

This is a continuation-in-part of our copending application Ser. No. 536,795, filed Mar. 23, 1966, now abandoned, which in turn was a continuation-in-part of our forfeited application Ser. No. 325,206, filed Nov. 15, 1963. The latter application was a continuation-in-part of forfeited application Ser. No. 198,049, filed May 28, 1962. The invention relates generally to the production of filamentary structures from synthetic linear polyamides and, more particularly, to an improved process in which such structures are drawn to increased length for the purpose of achieving orientation and high tensile strength.

When nylon was first introduced, orientation was accomplished merely by tensioning filamentary yarn between feed and draw rolls operated at differential speeds. Although product quality was acceptable, various difficulties such as differential dyeability were encountered as a result of nonuniform tensile properties and variable orientation along the length of the drawn yarn. Uncontrolled shifting of the draw point back and forth in the draw zone was soon found to be the cause of these and other difficulties. Subsequently, the use of a snubbing pin in the draw zone and localization of the draw point on the surface of the pin were disclosed by Babcock in U.S. Patent No. 2,289,232.

In the past, it has been recognized that the property uniformity of yarn spun from polyamides could be improved substantially by coupling two draw stages. However, it is also known that the successful employment of such a process depends on the close and effective control of variables. A commercially feasible process for the controlled multi-stage drawing of synthetic linear polyamide filaments has been disclosed by Zimmerman in U.S. Patent No. 3,091,015. In that process, yarn is drawn over a pin of the type disclosed by Babcock in the first stage and over a heated pipe, plate or the like in the second stage. Good product uniformity is obtained when the first-stage draw ratio falls within a range determined according to the birefringence of the feed yarn. Although yarn properties and uniformity are improved substantially, additional process considerations such as the application of finish to the yarn for the purpose of reducing friction are involved. To avoid variations in yarn properties, the amount, distribution and composition of the finish must be controlled carefully. Furthermore, for a given set of process conditions, there is an upper limit on the speed at which yarn can be drawn, established at least in part by the minimum time required for the uniform application of finish to each filament. As pin surface characteristics change with use, there are corresponding changes in finish application rate, the amount of heat developed by

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friction and hence in pin temperature. Such changes lead to yarn nonuniformities. Since the drawing characteristics of thermoplastic yarn are closely related to pin temperature, it has become the practice to heat draw pins for the dual purposes of obtaining improved polymer structure and simultaneously minimizing the effect of variations in the heat of friction. Where such heated pins are employed, there is a further limit imposed on drawing speed by the minimum contact time required to heat the running yarn sufficiently.

The most important objective of the present invention is to present process improvements which facilitate the multi-stage drawing of freshly spun nylon filaments of improved mechanical quality at higher speeds. Another important objective is to provide process improvements which permit control and localization of the draw point without resort to snubbing pins or the like. It is a corollary objective to provide a high-speed drawing process which is especially suited for direct coupling with the spinning process.

These objectives are accomplished in a process which includes the coupled steps of spinning filamentary nylon yarn and drawing the spun yarn in successive first and second stages. In the first stage draw zone, the yarn is passed through an enclosure wherein the draw point is substantially localized by jetting a heated gaseous fluid on the yarn and is drawn to the extent necessary to produce a degree of orientation corresponding to a total draw ratio of at least one and a half, but not over about four times, its unoriented length. The time-temperature-pressure relationship of yarn exposure to the fluid jet is such as to raise yarn spun from an aliphatic polyamide such as polyhexamethylene adipamide or polycapraamide to a temperature of at least 44° C., thereby reducing the drawing tension to no more than about 67% of the tension on the yarn under delocalized first stage conditions, i.e., in the absence of a fluid jet or a snubbing pin. With high modules, ring-containing polyamides, drawing tension is reduced to less than 80% of the tension under delocalized conditions.

Generally, as to all polyamides, the time-temperature-pressure relationship of yarn exposure to the fluid jet must be such as to raise the yarn to a temperature of at least about 50% of its glass transition temperature (T_g), thereby reducing the drawing tension to no more than about 80% of the tension on the yarn under delocalized first stage conditions.

Other objectives, advantages and characterizations will be apparent from the following specification and examples wherein reference is made to the accompanying drawings in which:

FIGURE 1 is a schematic illustration of an apparatus arrangement useful in the practice of the present invention;

FIG. 2 is an enlarged transverse sectional view of the jet enclosure shown schematically in FIG. 1;

FIGS. 3 and 4 show jet enclosure modifications used in place of that shown in FIG. 2 for purposes of comparison;

FIG. 5 is a graphic illustration showing the relationship between drawing tension and filament temperature; and

FIGS. 6 and 7 are graphic illustrations of the relationship between filament temperature and draw ratio for two different yarn counts.

In the process arrangement of FIG. 1, filaments 10 are spun from a nylon melt through a spinneret 12, quenched in a chimney 14, moistened in their travel over finish roll 16 and tensioned between first-stage feed and draw rolls 18, 20. Roll 20 has a higher peripheral speed than that of roll 18. From roll 20, the yarn

advances over a second-stage draw roll 22 to a conventional windup 24. Roll 22 has a higher peripheral speed than that of roll 20. Between first-stage rolls 18, 20, the filamentary yarn 10 passes through an enclosure 26 whereas second-stage draw roll 22 is enclosed in an air-heated oven 28.

As shown in FIG. 2, enclosure 26 includes a casing 40 having inlet and outlet apertures 42, 44 through which yarn 10 travels. In its passage through enclosure 26, the yarn is in grazing contact with guide pins 45-48. Within casing 40, there is a supply block 50 having passages communicating with the orifice in a jet plate 52 through which fluid is jetted onto the yarn in intersecting relationship therewith. Condensate is removed from casing 40 at 54.

In order to show the effect of the intersecting relationship between the yarn and fluid jet, certain tests have been run and comparisons have been made (Example VII), using devices differing from the jet enclosure 26 of FIGS. 1, 2. One of these devices has been illustrated in FIG. 3 and includes a cylindrical cell 60 having a circumferential slot 62, a fluid inlet 64 and a condensate outlet 66. Pressurized fluid jets from slot 62 in all directions, counter-current to yarn 10' at the input side and cocurrent at the output side. The device of FIG. 4 includes a casing 70 within which is situated a hollow abrasion-resistant pin 72 provided with a longitudinal outlet slot 74 across which the yarn 10'' passes as fluid is jetted thereon. Condensate is removed from casing 70 at 76.

As noted, higher levels of yarn uniformity are reached when the yarn temperature is raised to at least 44° C. in its passage through the jet enclosure 26 of FIGS. 1 and 2. At speeds in excess of 500 y.p.m., exposure time is less than 10 milliseconds. With such a substantially instantaneous increase in yarn temperature, much more stable operation and improved product uniformity are achieved. Although an abrupt increase in filament temperature within the jet enclosure is an essential feature of the present process, it is apparent that such temperature measurements oftentimes can only be made with great difficulty. Furthermore, in the lower range of operable filament temperatures, small variations can have a large effect (see FIG. 5) on drawing tension and, for that reason, the close control of process variables is important. In this respect, it has been found that the reduction in tension resulting from the transfer of heat to the filamentary structures in an accurate reflection of the yarn temperature in the jet enclosure. Both factors have been related to T_g since this temperature in turn is related to the mobility of the polymer chains which must be reoriented in the drawing process. Since the reduction in tension can be measured readily, it is also useful as a control parameter and has been reported herein as a process characterization.

The relationship between drawing tension and filament temperature for 34-filament yarn spun from 6-6 nylon at 825 y.p.m. and having an as-spun denier of 265 (Examples I-III) has been illustrated in FIG. 5. The complete curve for a first-stage machine draw ratio X_m of 2.3 as well as partial curves for higher draw ratios are shown. For this yarn count and draw ratio ($2.3X_m$), the yarn shows an exceptionally high uniformity (Example III) when heated to a filament temperature of about 56° C. The minimum operable filament temperature for the process of this invention corresponds to the break in the curve beyond which drawing tension decreases sharply. In practice, maximum filament temperatures are limited in order to maintain a tension of at least 20 grams on the yarn. If higher temperatures are employed, the threadline becomes unstable, interferes with adjacent threadlines and wraps on the succeeding roll.

As noted, minimum operable filament temperature corresponds to the point at which drawing tension decreases rapidly. That point has also been related and expressed in terms of a yarn temperature of at least about 50% of the glass transition temperature (T_g). Aliphatic poly-

amides such as 6-6 or 6 nylon have a T_g of about 90° C. The ring-containing polyamide of Example VIII (diamine of 70% trans-trans stereo-isomer content) has a T_g of about 180° C. Where used herein, T_g is the transition temperature associated with the onset of segmental motion by the polymer chains. This temperature is best determined by nuclear magnetic resonance (N.M.R.), as described, for example, by W. O. Statton in American Dyestuff Reporter, 54, No. 9, 26-32 (Apr. 26, 1965), in a paper entitled "Segment Mobility in Fibers as Shown by High Temperature N.M.R." The measurement should be carried out on undrawn filaments having only spinning orientation. An attenuation of 17 db should be used in determining the N.M.R. spectrum from which T_g is derived.

It is apparently unnecessary to provide enough heat to raise the axial temperature of each filament to the specified level, i.e., it is believed that raising the temperature of the surface layers to the required level is sufficient to initiate drawing. When drawing begins, the work done against internal visco-elastic forces raises the temperature inside the filament to the required level. This heating effect increases with draw ratio and is more pronounced when the draw point is localized, e.g., within a jet enclosure.

There is a direct relationship between spinning conditions and the machine draw ratio. The choice of a draw ratio depends on polymer viscosity and spun yarn orientation, as well as the subsequent treatment which the yarn will receive to prepare it for the particular use for which it is intended, i.e., the draw ratio is selected in order to produce a yarn of specific tenacity, elongation, modulus, dye-ability and the like.

The phrase "total draw ratio X" is used herein to take into account the several locations wherein orientation is introduced into the yarn. This orientation factor includes the conventional machine draw ratio X_m which is the ratio of feed and draw roll surface speeds if no slippage occurs. X_m also corresponds to the ratio of spun yarn denier divided by drawn yarn denier. Since the yarn entering the drawing stage may be under slight tension, an added predrawing stretch ratio X_p may have been imposed; usually this orientation factor is insignificant and can be ignored. The as-spun yarn also has a degree of orientation produced in the spinning process and measured by filament birefringence, which can be expressed as a draw ratio X_s . The value of X_s corresponding to any normal level of spinning birefringence may be determined by measuring the birefringence of yarn drawn to various low machine draw ratios, plotting the birefringences against the corresponding draw ratios, and extrapolating to zero birefringence. Typical values are listed below.

Birefringence:	Spinning draw ratio, X_s
0.000 -----	1.00
0.001 -----	1.022
0.002 -----	1.045
0.005 -----	1.116
0.010 -----	1.247
0.020 -----	1.543
0.025 -----	1.710

The total draw ratio X is the product of the component draw ratios, and is approximately: $X = X_s \cdot X_m$.

For some polymers, such as the one used in Example VIII, the refractive index measured parallel to the fiber axis is a better measure of fiber orientation than birefringence since changes in hydrogen bonding unrelated to orientation may affect the refractive index perpendicular to the fiber axis. A relation similar to the one listed above can readily be derived, using the appropriate refractive index.

The process which is improved by the practice of this invention is one which includes the coupled steps of spinning filamentary nylon yarn, drawing the yarn to produce an orientation corresponding to a total draw ratio X of at least 1.5 its unoriented length in a first stage, and further drawing the yarn in a separate second stage.

Because of the much higher filament temperatures which would be required, the total draw ratio X in the first stage should not exceed about 4. The orientation produced by spinning and drawing in the first stage can be distributed in any convenient manner; in general, high spinning speeds produce high spinning orientation and require a corresponding reduction in first stage machine draw ratio.

When the first-stage total draw ratio X has been selected, the operable filament temperature range for 6-6 nylon can be read from within a plotted area of the type shown at ABCDE in FIG. 6 and the actual first-stage draw ratio X_m can be calculated from the equation:

$$X_m = X/X_s$$

At a given draw ratio X_m , filament temperatures outside area ABCDE lead to yarn of poor mechanical quality, having many drawing breaks, broken filaments, etc. Observed fluctuations in drawing tension are indicative of these unsatisfactory conditions.

The maximum total draw ratio X corresponding to point C in FIG. 6 limits first-stage drawing to orientation of a type which is believed to involve the uncoiling and straightening of polymer chains. Above that maximum, the relative movement of larger structural units such as bundles of oriented and partially crystalline polymer chains, requiring much higher drawing tensions, is involved. This type of molecular orientation is best accomplished at higher temperatures in the second stage. Any attempt to draw in the first stage at such higher temperatures or at draw ratios corresponding to the above-mentioned higher drawing tensions leads to a greater number of broken filaments.

Operability curves similar to that shown in FIG. 6 can be defined for other yarn counts, for various drawing speeds and for yarns spun from polymer of a different relative viscosity. Since the relationship between these variables is a complex one, the curves do not normally superimpose. Such a curve for 720 denier, 20 filament yarn spun from 6-6 nylon having a relative viscosity of 60 at a speed of 550 y.p.m. has been shown in FIG. 7. Although the curves of FIGS. 6 and 7 do not superimpose, it is apparent that the operable filament temperatures are functionally related to denier, drawing speed and polymer viscosity.

For the various tests and measurements reported in the following examples, yarn samples are obtained by stripping representative 130 to 150 cm. lengths from the extremities and from the longitudinal center of a package, throughout the entire package and yarn length.

Where retraction is reported, sample length is determined immediately after removal from the package, by tying the ends together, hanging a weight of about 0.1 g.p.d. in the loop, and measuring loop length. After exposure for 24 hours at 75° F., 72% relative humidity, loop length is measured again and percent retraction is calculated.

For shrinkage values, yarn samples are taken from packages which have been conditioned for at least 24 hours at 75° F., 72% relative humidity. After determining the initial length, a loop of conditioned yarn is submerged in boiling water for about 20 minutes and then dried for about 25 minutes under 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.

The "initial modulus," represented by the symbol M_1 , is defined as the ratio of change in stress to strain in the first reasonably linear portion of a stress-strain curve. The units employed herein make the initial modulus numerically equivalent to 100 times the force in grams per denier required to stretch the specimen the first 1%. In the examples, modulus is obtained from yarn stress-strain

curves recorded on an Instron Tensile Tester of the type which stretches the yarn at a constant rate of elongation. From the stress-strain curve, the slope of the initial straight line portion is determined graphically. Tenacity and break elongation are also read from the curve. All yarn tested was conditioned on the package for at least 24 hours at 75° F., 72% relative humidity, prior to testing.

Relative viscosity is determined as described in U.S. Patent No. 2,385,890.

Example I

Poly(hexamethylene adipamide) having a relative viscosity of 40 is spun to 34-filament yarn at a spinning speed of 825 y.p.m. in an apparatus arrangement of the type shown in FIG. 1. The as-spun yarn, having a spinning orientation factor X_s of 1.3, advances to the first-stage feed roll at the spinning speed. The machine draw ratio X_m in the first stage is 2.3. In different runs, the yarn is drawn in the absence of a first-stage pin or yet (GA), through an enclosure of the type shown in FIG. 2 from which pins 45-48 have been removed (GB) and through a similar enclosure (GC) provided with grazing pins located outside the enclosure, as close together as possible and almost touching the enclosure; these pins touch but do not pinch the yarn. In runs GB and GC, 2 lb./hr. of saturated steam is supplied to the jet at a pressure of 2 p.s.i.g. and flows through the jet orifice at a velocity of 400 ft./sec. Second-stage conditions are the same for all runs. In each instance, total denier of the drawn yarn is 70. Comparative results are reported in the following table:

TABLE I

Run	Threadline tension, gr.	Max. filament temp., ° C.	Variance of breaking strength, σ^2 (gr. ²)
GA	80	35	1.05
GB	60	48	
GC	53	51	0.67

In run GA, the draw point is not localized and non-uniform yarn is produced. Breaking strength of yarn from run GC, in which 100% of the draw was localized within six inches of the jet, is much more uniform as evidenced by the tabulated variance values. Upon repetition of run GC under conditions giving a tension of 46 gr., the strength variance (σ^2) is further reduced to 0.26 gr.². As between GB and GC, it is apparent from the higher temperature and lower tension of GC that heat is transferred more efficiently when grazing pins are employed to break up the boundary layer of air on the moving yarn. When the pins 45-48 are replaced, further improvement is noted in both GB and GC.

Example II

Under the same conditions as in Example I, quenched yarn is drawn in two stages to a total denier of about 70. In run HA, two draw pins about which the yarn makes an S-wrap (contact, 300 degrees) are used in place of the enclosure 26. In run HB, the yarn is heated to a temperature of 58° C. by feeding 105° C. steam at 3 p.s.i.g. to the jet orifice; exposure time in the enclosure is less than 8 milliseconds. Gas velocity is Mach 0.38. In each run, spinning speed is 825 y.p.m., spinning orientation factor X_s is 1.3, first-stage draw ratio X_m is 2.3 and total first-stage draw ratio X is 3.0. In the second stage of each run, the yarn is stabilized by exposure to hot air at 190° C. and the draw ratio is adjusted to give comparable break elongations in the different runs. Both

yarns are packaged on underdriven (6.5%) windups. Comparative results are reported in the following table:

TABLE II

	HA	HB
Draw ratio (total, all stages).....	4.2	3.8
Tenacity, g.p.d.....	5.5	6.1
Elongation, percent.....	27	28
Initial modulus, g.p.d.....	28	29
Boil-off shrinkage, percent.....	8	6
Twenty-four (24) hour retraction, percent.....	0.4	0.2
Denier variation, percent C.V.....	2.5	1.9
Broken filaments per million yards.....	25	10
Operability, breaks per pound.....	0.096	0.003

From these comparisons, it is apparent that yarn processed in accordance with the present invention (HB) exhibits improved viscoelastic properties, dimensional stability, mechanical uniformity and processability. It should be noted that test yarn HB was drawn at a lower total draw ratio and yet had a higher tenacity.

When the test was repeated, using yarn spun from high viscosity, vacuum-finished poly(caproamide), similar comparative results were obtained.

Example III

As noted above, FIG. 6 shows the relationship between filament temperature and total draw ratio X in the first stage for 265-denier, 34-filament yarn spun at 825 y.p.m. from molten poly(hexamethylene adipamide) having a relative viscosity of 40. Such yarn has a spinning orientation factor X_s of 1.3. In different runs, it is drawn in two stages to a total denier of 70 under the conditions given in the following table:

TABLE III

Run No.	First stage draw ratio X	Jet conditions saturated steam			Filament temp., °C.	Drawing tension, gr.	Tension, percent of unheated control	Processability
		P.s.i.g.	° C.	Lb./hr.				
IA.....	3.0	2.5	104	3.2	55	40	47.0	Good.
IB.....	3.0	5	109	4.6	72	9	10.6	Poor.
IC.....	3.0	0	-----	-----	35	85	100	Fair.
ID.....	3.9	5	109	4.6	71	56	66	Good.

In IB, tension was too low and the threadline broke down. In IC, mechanical quality was poor, showing an average of five defects per million yards. It should be noted that both of these runs fall outside of the operable area ABCDE shown in FIG. 6.

Example IV

Poly(hexamethylene adipamide) having a relative viscosity of 60 is spun to 20-filament, 760 total denier yarn at a spinning speed of 540 y.p.m. and drawn under the conditions given in Example I. One threadline (JA) passes through the fluid jet, as in Example I. Another threadline (JB) passes through the jet enclosure but is routed around the fluid jet. In both runs, saturated steam is delivered to the jet at 5 p.s.i.g. and the first-stage total draw ratio X is 2.88. The respective yarns are heated to temperatures

of 60° C. (JA) and 54° C. (JB). Although exposed to a steam atmosphere, the yarn from run JB exhibited poor mechanical quality in the form of repeated breaks on the second-stage feed roll 20 (FIG. 1).

Example V

The heavy denier, as-spun yarn of Example IV (spinning orientation factor X_s of 1.25) is drawn in an apparatus arrangement of the type shown in FIG. 1 under various steam jet conditions. In each run, the first-stage draw ratio X_m is 2.1, giving a total first-stage draw ratio X of 2.62. Following second-stage drawing at constant draw ratio, samples of each yarn are broken in order to permit determination of the variance in breaking strength (σ^2). Comparative conditions and results are reported in the following table:

TABLE V

Run No.	Jet conditions saturated steam		Filament temp., °C.	Drawing tension, gr.	Tension, percent of KA	Variance of break strength, gr. ²
	P.s.i.g.	° C.				
KA.....	-----	-----	58.5	125	100	9.5
KB.....	2.2	103.7	61.5	85	68	9.5
KC.....	3.6	108.2	65.5	60	48	5.0
KD.....	4.0	106.6	67.0	55	44	4.0

From these comparisons, it is apparent that yarn strength uniformity is improved as drawing tension decreases and maximum yarn temperature increases. It should be noted that all of runs KB-KD fall inside the operable area ABCDE of FIG. 7.

Example VI

Run IA of Example III is repeated except for the omission of casing 40 from enclosure 26 (FIG. 1) and an

increase in steam pressure to 10 p.s.i.g. Filament temperature is increased over GA by 9° C. to 44° C. Drawing tension is reduced to 73 gr., i.e., to 92% of the tension in unheated control run GA. When the test is repeated, with the casing replaced, the temperature is increased by 47° C. to 82° C. Drawing tension is reduced to 2 gr. The advantages of exposure within an enclosure are apparent from these comparisons. The inoperable tension level of the second run could have been brought to an acceptable level by a reduction of steam pressure, e.g., to 2 p.s.i.g. as in Example I.

Example VII

Under conditions otherwise similar to those of Example VI, yarn is drawn through the enclosures of FIG. 3 (LD,

LE) and FIG. 4 (LA-LC). Steam conditions and results obtained are reported in the following table:

TABLE VII

Run No.	Steam pressure, p.s.i.g.	Drawing tension, gr.	Tension, percent of control GA	Maximum-minimum filament diameter (arbitrary units)
LA.....	0.11	75	94	0.10
LB.....	0.27	60	75	0.04
LC.....	0.69	35	44	0.04
LD.....	1.62	65	81	0.09
LE.....	4.70	40	50	0.06

From the filament diameter spread comparisons, it is apparent that yarn quality is higher when the fluid jet intersects the yarn (FIG. 4) than when yarn and jet flow (cocurrent and countercurrent) are parallel (FIG. 3). It is also apparent that product quality is improved as drawing tension decreases.

In run LE, tension variation in the threadline over a 2-minute period was ± 7.5 gr., as against ± 6.0 gr. for run IA (Example III). This comparison is indicative of the higher uniformity obtained when the fluid jet intersects the yarn.

The process of this invention has its major utility in drawing polyamide yarns at high speeds and at short gaseous-fluid contact times. Although marked improvements are obtained at spinning speeds of 500 y.p.m., the use of higher gas velocity jets permits drawing at spinning speeds of 1000 to 3000 y.p.m., by operating at exposure times (in the jet enclosure) of the order of 0.001 second.

The instant multi-stage drawing process may be followed by or combined with such important operations as annealing, setting, relaxing, twisting, crimping, alternate twisting, false twisting, and/or the like. It is also useful in drawing filaments of modified cross section, e.g., "Y," propeller-shaped, trilobal, etc., since substantially no distortion of the desired cross section attends such drawing.

The filamentary structures of this invention may contain the usual textile additives such as delusterants, antioxidants, and the like. Suitable antioxidants are disclosed in U.S. Patents Nos. 2,705,227; 2,640,004; and 2,630,421. Other useful additives are disclosed in U.S. Patents Nos. 2,510,777 and 2,345,700. In addition, finish may be applied to the structures, though the uniformity of application of finish is not nearly as critical as when drawing over or about snubbing elements.

After drawing with hot air or super-heated steam, it may be desirable to treat the yarn with moisture or an aqueous finish, preferably prior to packaging, in order to permit the yarn to regain its normal or equilibrium moisture content. Such moisture may be conveniently applied during a subsequent relaxation procedure, using steam as the relaxing medium.

Any gaseous fluid reasonably inert to the yarn (e.g., steam, hot air, nitrogen, carbon dioxide or mixtures thereof) may be employed as the plasticizing medium, steam being preferred in most applications because of its high heat transfer coefficient. When saturated steam is used, high quality steam is preferred. Fluid pressure requirements and hence fluid consumption are related to the dimensions of the fluid jet. Accordingly, when drawing higher or lower denier yarns, it may be desirable to increase or decrease, respectively, the jet dimensions in order to change the flow of fluid, thereby compensating for the greater or lesser mass of such filaments.

The process of this invention is useful in the drawing of most melt-spinnable synthetic linear polycarbonamides or "nylons," such as those disclosed in U.S. Patents Nos. 2,071,250 and 2,071,253. The preparation and spinning of these compounds is described in U.S. Patents Nos. 2,130,948; 2,163,636 and 2,477,156. It is especially useful for those polyamides having a low or intermediate second order or "glass" transition point, i.e., having a T_g

in the neighborhood of 50-100° C. Examples of such polyamides are those prepared from suitable diamines and dibasic acids, e.g., from hexamethylene diamine and adipic acid and their amide-forming derivatives, and also from terminal amino carboxylic acids, e.g., from omega amino caproic acid, omega amino-undecanoic acid, and their amide-forming derivatives, such as caprolactam. Copolyamides, grafted polyamides, and blends of polyamides with other compatible polymers may also be employed in the process of this invention.

As indicated, the process disclosed herein is useful with a wide variety of synthetic linear polycarbonamides. In addition to those previously mentioned, it has been found to be particularly useful in the orientation of filaments spun from the polyamide of bis(p-aminocyclohexyl) methane and dodecane dioic acid, as described in the following example.

Example VIII

Equimolar amounts of bis(p-aminocyclohexyl)methane and dodecane dioic acid are reacted in an autoclave substantially as described in U.S. Patent No. 2,512,606; the resulting polyamide has a relative viscosity (as defined in U.S. Patent No. 2,385,890, using 98% formic acid as solvent) of 77. The polymer is extruded, cut to flake and spun to yarn, using the steam spinning process of Waltz U.S. Patent No. 2,571,975). The yarn is extruded through a 34-hole spinneret at a temperature of 310° C. and a spinning speed of 645 yards/minute. The spun yarn has a birefringence of 0.006. The yarn is drawn without intermediate packaging, according to the process of FIG. 1. In a first test, run MA, heated air is jetted in intersecting relationship onto the yarn line in the first draw zone, localizing the draw point. The jet body is heated to about 140° C.; the air pressure is 90 p.s.i.g. The machine draw ratio X_m in the first stage is 1.59; the total machine draw ratio X_m is 3.24. The air temperature in hot chest 28 is 205° C. The final yarn denier is 63.8. The drawing tension in the first drawing zone is 95 to 100 grams. The coefficient of variation of the denier is 2.2.

When the test is repeated (run MB) without using the jet, the drawing tension is 125 to 130 grams. The coefficient of denier variation is 3.2, showing a lesser degree of uniformity.

It is apparent that many changes and modifications may be made in the disclosed process without departing from the spirit of the present invention which is therefore intended to be limited only by the scope of the appended claims.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. A process including the coupled steps of spinning filamentary nylon yarn, drawing said yarn to produce an orientation corresponding to a total draw ratio of at least one and a half and less than four in a first stage and further drawing the yarn in a separate second stage, the improvement of which comprises: passing the yarn through an enclosure situated in the first-stage draw zone and, in said enclosure, substantially localizing the draw point by jetting a heated gaseous fluid on the yarn in intersecting relationship with its path of travel through the enclosure, said yarn being passed in grazing contact with guide pins in the approach to and departure from the fluid jet but being free from snubbing contacts in said draw zone.

2. The process of claim 1 wherein said nylon consists essentially of polyhexamethylene adipamide and wherein the time-temperature-pressure relationship of exposure to said fluid is such as to raise the yarn to a temperature of at least 44° C. and to reduce the drawing tension to no more than about 67% of the tension on the yarn in the absence of said fluid.

3. The process of claim 2 wherein said yarn is passed in grazing contact with guide pins in the approach to and departure from said enclosure.

4. A process including the coupled steps of spinning
 filamentary yarn from a nylon melt at spinning speeds in
 excess of 500 yards/minute, quenching the spun yarn and
 drawing the quenched yarn to produce an orientation cor-
 responding to a total draw ratio of at least one and a half
 and less than four between first stage feed and draw rolls
 and further drawing the yarn in a separate but coupled
 second stage, the improvement of which comprises sub-
 stantially localizing the first-stage draw point in spaced
 relationship to the first-stage feed and draw rolls by pass-
 ing said yarn through an enclosure and, in said enclosure,
 jetting a heated gaseous fluid thereon, from one side there-
 of, the time-temperature-pressure relationship of exposure
 to said jetting fluid being such as to raise the yarn to a
 temperature which is at least 50% of T_g and to reduce the
 drawing tension to no more than about 80% of the ten-
 sion on the yarn in the absence of said fluid, said yarn

being passed in grazing contact with guide pins in the ap-
 proach to and departure from the fluid jet.

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