PROCESS FOR SPINNING POLYBLEND YARN


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SUMMARY OF THE INVENTION

In accordance with the present invention, it has been found that for melt spinning blends of polyester dispersed in nylon, four parameters of the melt spinning operation are critical. They are an intensified shear in the extruder, and an intensified shear at the spinneret, compared to that developed at the corresponding stages in the total operation for melt spinning of the nylon ingredient of the blend; maintenance of temperatures throughout the melt in the range of 275°±10° C.; and flow of the melt into the spinneret capillary with gradual convergence of the stream, whereby the melt bulge in the extruded filament will not exceed a diameter of about 1.4 mm, when the longitudinal dimension of the capillary cross section is up to 0.35 mm., and a die swell factor not over 4 when said dimension exceeds 0.35 mm. It is then possible to melt spin and to draw the selected polyester dispersions in nylon at performance levels comparable with the melt spinning and drawing performance of nylon processed under commercial conditions.

At the same time, it is found, the continuous multifilament yarn which is produced is of superior quality to that obtained when any of the above factors are outside their critical ranges. In particular with respect to the high tensile modulus, the good fatigue properties, and the uniformity of properties which can be achieved by use of the present process, the multifilament yarn obtained is materially improved over that obtained under conditions outside the ranges of this invention. The filaments obtained by this invention are found to contain in each transverse cross section a much larger number of reinforcing polyester fibrils than are produced from like blends spun otherwise; this contrast remaining true even when the conventional operation of the nylon extruder is modified in the comparison tests, to produce the same degree of dispersion of polyester in the melt as is formed when operating in accordance with this invention. The effects of spinneret shear is particularly important as will appear below.

Although the principles underlying the invention are at best only partially understood, it appears the fineness and correspondingly large number and the great lengths of polyester fibrils obtained by the present process are critically important features in the high performance of the resulting yarn products. The average diameters of the fibrils in yarn of this invention, drawn at 5:1 draw ratio, are not over 0.15 micron. Typically the fibrils in the drawn yarn obtained by the present process have about 0.05 to 0.15 micron average diameter in yarn drawn 5x (i.e. drawn at draw ratio of 5:1) and spun from about 25-60 parts by weight of PET (polyethylene terephthalate) and correspondingly 75-40 parts of polycapraomide. The average number of fibrils in the 5x drawn polycapraomide yarns of this invention, per 1000 sq. microns transverse area, is at least 15,000 and in the best mode of operation is from at least 30,000 to as high as 1,000,000. The length: diameter ratio of these fibrils of preferred operation averages about 1,500:1. At lower weight ratios of PET/nylon-6, such as 4/96, 10/90 and 20/80 by weight, typical drawn fibrils per this invention have progressively smaller average diameters, ranging about 0.02 micron, about 0.03-0.04 micron, and about 0.04-0.06 micron average diameter respectively in the yarn drawn 5x. The average number of fibrils per transverse 1000 sq. micron area of 5x drawn yarns of this invention, having 4-20 parts of polyester dispersed in correspondingly 96-80 parts of nylon by weight, is typically about 50,000-1,000,000. At and below 15 parts of polyester by weight, per 100 parts of nylon and polyester in the composition the 5x drawn yarns of this in-
vention contain a minimum of 30,000 fibrils per average 1000 sq. micron transverse area. When properties are referred to herein, it is to be understood they are averages arrived at by systematically sampling large quantities of yarn produced under given conditions, in quantities ranging from scores to hundreds of pounds for laboratory production, and hundreds to thousands of pounds for pilot plant production. Particularly with respect to spinning and drawing performance, verification of high performance levels requires data from both the spinning and drawing of several thousands of pounds of yarn produced under given conditions, for the reason that at high performance levels, the combined occurrence of drips and breaks is of the order of 10 or 15 per thousand pounds of polymer spun. In the Tables of Examples below, data obtained on laboratory scale and those on pilot plant scale are so indicated.

Definitions, formulae and tests

"Drips"—During melt spinning of multifilament yarn, a rupture of one of the individual filaments where it is molten, at or near the spinneret, may occur, due e.g. to gel or sign of polymer weakening the filament, or partial blockage of polymer flow through one hole of the spinneret, etc. The filament thereby extruded from the affected spinneret hole will no longer be under take-up tension. It will hang or descend slowly, collecting molten polymer in a blob which carries the filament down the stack under its own weight. The loose filament with its heavy blob, unless prevented, will usually snag other filaments in the bundle before or during wind-up of the undrawn yarn package so that the yarn breaks when the package is being unwound.

A "drip catcher" is provided at the bottom of the quench stack, to detect the large blob and signal the operator to remove the package of yarn being wound up, wipe the spinneret, and start a new yarn package. The frequency of these drips is counted and is reported herein as "drips per 1000 pounds" of polymer processed. In preferred operations in accordance with this invention, the drips average no more than 5 per 1000 pounds on the average.

"Breaks"—In the drawing process, one segment of yarn, e.g. formed from non-homogeneous melt, may not draw as much without breaking as does the main yarn. The result is that this segment will break, e.g. in the drawing zone, and the drawing operation must be shut down and restarted. Such occurrences are called drawing "breaks." Their frequency is reported herein as "breaks per 1000 pounds" of first quality yarn produced. The sum of drips and breaks measures performance as reported herein. It will be appreciated that breaks can generally be reduced by reducing the draw ratio; however this will generally result in lowering the tensile strength and modulus of the yarn. The preferred undrawn yarns produced according to this invention are drawable by at least 5x without more than 10 breaks per 1000 pounds on the average.

Melt viscosity (poises)—As reported herein, measured by use of an Instron Melt Rheometer with 50 mils diameter capillary 4 inches long, and with a conical entrance having angle of convergence of 60° (i.e. elements at opposite sides of the entrance cone converge in the direction of flow, at an angle of 60° at the apex). The melt viscosities are standardized to a temperature of 275° C. and velocity gradient of 3000 reciprocal seconds.

Reduced viscosity (deciliters per gram)—As reported herein, determined at 25° C. and polymer concentration of about 0.5 gram per 100 ml. in purified ortho-chlorophenol containing 0.1% by weight of water. (See the above-cited Twilley application Ser. No. 368,028 at page 8, lines 9-20.)

Mixing temperature (° C. )—As reported herein, measured by a thermocouple in a well protruding into the melt at the extruder. 

Apparent mixing shear (Sec. -1 )—Expressed herein in terms of shear rate, i.e. velocity gradient of mixing in reciprocal seconds, under the assumption that viscosity is constant. In a screw extruder, this mixing shear is given by the formula: \( \frac{d (r.p.s.)}{H} \), wherein \( d \) is the screw diameter, r.p.s. is the revolutions per second of the screw, and \( H \) is the depth of the channel between the screw threads in the metering section of the extruder, in the same units as \( d \).

Spinning temperature (° C.)—As reported herein, measured by a thermocouple in a well protruding into the melt at the inlet face of the spinneret.

Apparent pipe and spinneret capillary shear (sec.-1 )—Expressed herein as linear velocity gradient through each pipe, or each capillary hole of the spinneret, in reciprocal seconds, under the assumption that viscosity is constant. Given by the formula: \( \frac{q}{\pi r^2} \), wherein \( q \) is the volumetric flow per second per pipe or spinneret hole, e.g. cubic feet per second per hole, and \( r \) is the radius of the pipe or the spinneret hole capillary in the same linear units as for \( q \), e.g. feet.

Jet velocity (feet per minute)—Given by the formula: \( \frac{q}{\pi r^2} \), wherein \( q \) is the volumetric flow in cubic feet per minute per hole, and \( r \) is the radius of the spinneret capillary in feet.

Melt density (gm./ml.)—In calculating volumetric flow rates (q) from the throughput in weight units per hour, the following values are used for melt densities at 270° C.: 

<table>
<thead>
<tr>
<th>G./ml.</th>
<th>10/90</th>
<th>20/80</th>
<th>30/70</th>
<th>40/60</th>
<th>50/50</th>
<th>60/40</th>
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<tr>
<td>1.03</td>
<td>1.05</td>
<td>1.07</td>
<td>1.09</td>
<td>1.11</td>
<td>1.13</td>
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</table>

Melt bulge (mm.)—A bulge with diameter greater than that of the spinneret capillary, observed in emerging molten filaments just below their point of emergence from the spinneret. Diameter of melt bulge is measured by photographs of the emerging filaments.

Stack draw down—Ratio between take-up speed of undrawn yarn in e.g. feet per minute and jet velocity (in the same velocity units).

Diameter of polyester particles (D) in the extrudate (microns)—The molten filaments are cut a few inches below the spinnerette, releasing the take-up tension on the filaments being extruded; and the forward flow of molten polymer from the spinnerette holes is collected on a tray in the form of relatively thick films which quickly solidify on the tray. A three-milligram sample is dissolved at 25° C. In 200 cc. of aqueous formic acid which dissolves the nylon component and leaves a dispersion of the polyester component in the aqueous formic acid solution. The polyester is in the form of spherical and slightly elongated particles. One gram of potassium chloride is added to render the liquid phase conductive and the dispersion is then passed through a Coulter Counter (Model A) with a 30 micron aperture. The counter determines the average particle volume (V) and the volume distribution. Assuming the particles to be spherical, the average diameter (D) of the dispersed polyester particles, reported herein, and its standard deviation is calculated using the formula:

\[ V = \frac{4}{3} \pi (D/2)^3 \]

Polyester fibril lengths in undrawn yarn (microns)—

These lengths as reported herein are averages, measured from photomicrographs of lengthwise sections of undrawn yarn stained with a dye for the nylon ingredient which does not dye the polyester; e.g. by immersion in a boiling 0.07% aqueous solution of Brilliant Acid Blue dye for one hour.
Polyester fibril lengths (L) in drawn yarn (microns)—
These lengths (L) are averages calculated by multiplying the fibril length in the undrawn yarn by the draw ratio. These calculated values agree with observations by electron microscope.

Diameter (d) of Polyester fibrils in the drawn yarn (microns)—These diameters are too small to be accurately determined with an optical microscope. Average diameter (d) as reported herein is calculated from polyester fibril lengths, L, in the drawn yarn, as above defined, by the formula:  
\[ d = \frac{D}{\sqrt{15L}} \]  
wherein D is the diameter of polyester particles in the extrudate, as above defined. The drawn polyester fibril diameter, thus calculated, has been checked by electron microscope measurement and found to agree within ±0.01 micron.

Number (N) of polyester fibrils/1000 sq. microns of traverse filament area—As reported herein, (N) is calculated from the above defined diameter (d) of polyester fibrils in drawn yarn by the formula:

\[ N = \frac{1000F}{\pi(d/2)} \]  

wherein F is the weight fraction of polyester in the forming blend and (d) is the above defined fibril diameter. The density of the fibril is that of drawn polyester, e.g. 1.38 gm./ml. for polyethylene terephthalate; and the density of the filament is given by: 1/r (F/density of drawn polyester) + (1-F)/density of drawn nylon).

By electron microscope observation of a typical yarn, the count of fibrils per 1000 sq. microns transverse area was 33,200 vs. 27,200 calculated, indicating that these calculated counts are a good estimate of the true average values.

Solid polymer moisture content (percent by wt.)—A sample from a sealed container of the polymer (about 5 grams) is weighed to 0.1 mg. precision under strictly anhydrous conditions in a vial, then is maintained at reduced pressure (100 mm. Hg absolute) and at 185° C. for 2 hours. The pressure of the evolved water vapor, exerted on an oil manometer, is measured. The water content of the sample is determined from the measurement of water vapor pressure, by use of a calibration curve.

Yarn properties—As reported herein these are determined by the usual standard tests below indicated:

(a) Tensile strengths (UTS, in gms./denier) are those measured on drawn polyester IP-4 Tensimeter. (Each determination is the average of five breaks per card.)
(b) Ultimate Elongation (UE, in percent)—As for UTS.
(c) Toughness Index is given by the formula: (UTS) X (UE)\(^{4}\).
(d) Flat spot index—A measure of primary creep, by the method of Twitley, U.S. Application Ser. No. 368,028 above cited, p. 18, line 1—p. 19, line 17.
(e) Initial tensile modulus (gms./denier) is measured on the Instron instrument, as the slope of the first linear portion of the stress-strain curve, \( \times 100 \).
(f) Hot wet mechanical properties are determined as above on drawn yarn held under water at 95° C.
(g) Fatigue resistance is measured (in minutes at 30 p.s.i.) by ASTM Standard Test of 1964, Part 25, Test D-885 upon two-ply (2x840, 122x125 twist) tensilized cord (Goodyear Tub Fatigue Test).
(h) Recovery (percent)—As herein reported, determined with the Instron instrument at 65% relative humidity and 70° F. (21° C.) and given by the formula:

\[ 100 \times \frac{\text{area under the stress-strain curve for recovery from 1% elongation}}{\text{area under the stress-strain curve for 1% elongation}} \]

(i) Adhesion to rubber (lbs.)—Measured by standard "H" adhesion test employing tensilized two-ply cords (2/804, 122x125 twist, with standard resorcinol-formaldehyde-latex finish and with 1/4 inch of cord embedded in natural rubber. Reported value is average force in pounds to pull one test cord from the rubber at 250° F. (121° C.).

Dye strengths and uniformity—Dyeing is accomplished with Color Index Disperse Blue 3 (a water insoluble anthraquinone dye) using 0.2% by weight on fabric or yarn in a dyebath at 95° C. (205° F.). Dye strength (based on nylon as 100) and uniformity (freedom from streaks and bands, rated from (1) for excellent to (4) for poor) is judged by a panel of skilled observers.

Birefringence—A measure of the extent of molecular orientation in the direction of the extruder, as measured, defined as the difference in the refractive index measured longitudinally of the filament vs. that measured perpendicular to the axis of the filament.

The four critical melt spinning parameters, and values thereof used in this invention, are discussed in detail in the following, together with other conditions which are important for best results in the practice of this invention.

The critical stages at which shear normally used in melt spinning nylon-6 should be intensified, in accordance with this invention, are in the melt prior to its formation into filaments, and in the melt during extrusion of the molten dispersion of polyester in polyamide through the spinneret holes. The application of intensified shear at each of these successive stages at essential for high quality spinning and drawing performance.

The specific requirements of mixing shear in the present process depend upon variables which influence the proportion of polyester in the dispersion, the time of mixing, and the time and shear during transfer of the molten dispersion from the mixing apparatus used. A useful criterion of proper mixing shear has been found to be the particle size (i.e. average diameter) of the dispersed polyester particles in the extrudate, collected free of tension in molten form just below the spinneret. These polyester particles are observed microscopically in differentially stained cross sections of the extrudate to be spherical or slightly elongated. Similar sized polyester particles are observed in polymer blends collected at various points between the extruder and the inlet face of the spinneret.

In general the average particle diameter of the polyester dispersed in the molten nylon is somewhat smaller, the nearer the point of sampling is to the extruder outlet; e.g. 1.39 microns at the extruder outlet, 1.66 microns over the inlet face of the spinneret, and 1.80 microns in the collected extrudate for 30/70 weight blends of polyethylene terephthalate/nylon-6 have been observed in typical operations in accordance with this invention. It will be appreciated, accordingly, that results obtained by high mixing shear can and should be preserved by transferring the dispersion in relatively narrow pipes which will exert continuing shear such that the particles do not increase unduly in size during transfer.

It has been found that for reasons not at present fully understood, the higher the proportion of polyester in the dispersion, up to about a 50/50 weight ratio, the larger will be the particle size of the dispersed polyester which will still give good results in spinning, and in the yarn obtained; but at 60/40 weight ratio the desired particle size is below the 50/50 level. Also, structure of the polyester influences the permissible particle size, in the sense that a polyester having 2 rings in the chain unit can have a larger particle size than when there is only 1 ring and still give good spinning and drawing performance, per our data.

The above parameters can be correlated over the range to about 60/40 ratios by weight of polyester/nylon by the following relation between desired average particle diameter D in the extrudate in microns; parts by weight P of the minor ingredient of the blend, based on the poly-
ester/polyamide mixture as 100; and number of rings C (C being 1 or 2), in the polyester chain unit:

\[ D \leq 0.04 P + 0.4 C \pm 0.25 \]

For instance when the polyester is polyethylene terephthalate in weight proportion of 30/70 with nylon, P is 30 and D in accordance with the above formula is at most 1.85 microns.

When the polyester particles have average diameters about the maximum specified above of about 3 microns, the standard deviation of these diameters turns out to be about 0.25 micron; and for lower average diameters the standard deviation is also lower; so that 0.25 micron represents a maximum for standard deviation of the polyester particle diameters at desired particle size.

In general the values, in accordance with this invention, observed for average diameter D in given blends will depend on intensity of mixing shear and will range down below the permissible maximum in an interval up to about 0.5 microns as the mixing shear is intensified. There is, however, a point at which the effect of increased mixing shear begins to level off and moreover, such increased shear requires higher power and tend to build up the temperature in the melt. Accordingly the value for polyester particle diameter \( D \) in the extrudate (in microns) in accordance with this invention will generally be in the range given by:

\[ D \leq 0.04 P + 0.4 C \pm 0.25 \]

When a conventional nylon single screw extruder with a metering section is used to mix the molten polyamide/polyester dispersion, the apparent mixing shear therein, expressed in terms of velocity gradient, should be at least 80 reciprocal seconds, preferably in the range 120-200 reciprocal seconds. A velocity gradient in the pipes of 50-100 reciprocal seconds is generally suitable to maintain the particle size in the desired range during transfer.

Mixing shear and spinneret shear together, as previously noted, have been found to cooperate, critical levels of both being required for securing major beneficial effect, both on spinning and drawing performance, and on properties of the drawn filament, e.g. in particular on the tensile modulus and fatigue properties.

Specific values of spinneret shear, in terms of velocity gradient through the spinneret hole, which must be used to obtain performance which may be accomplished by this invention start well above the values (about 2000 reciprocal seconds) ordinarily used in commercial spinning of nylon. Marginal performance starts at about 3000 reciprocal seconds and generally improves as the velocity gradient increases. Velocity gradients through the spinneret hole of at least 5,000 reciprocal seconds, and still higher values up to about 30,000 reciprocal seconds are beneficial. Above a velocity gradient of about 30,000 reciprocal seconds the benefits of intensive spinneret shear appear to drop off.

It is possible to observe directly the effect of spinneret shear upon the polyester particles in the subject dispersions by the following procedure. The filaments are cut, leaving them of tension in the zone where still molten below the spinneret; the molten free end of the filament retracts and makes a blob. A tube full of water is held under the blob and is raised up to the spinneret hole so that the molten polymer extrudes directly into the water. The sample of extrudate thus collected tapers from the thick blob to a stem, of diameter about equal to the spinneret hole diameter, formed from quickly chilled polymer collected as it was emerging from the spinneret hole.

Longitudinal sectioning of these samples and microscopic observation of the differentially stained section reveals long, relatively thin polyester fibrils in the "stem." In extrudate from 30/70 weight ratio blends of polyethylene terephthalate/nylon-6 these fibrils average about 50-100 microns long and about 0.2-0.3 micron in diameter. In the sections taken progressively along the filament as it thickens toward the blob at the end, the fibrils become shorter and thicker until in the thickest part of the sample, at the blob on the end, only spherical or slightly elongated particles, like those observed in the extrudate previously described, are found. These have diameters in the same general range as for the particles in the previously described extrudate, viz. about 1.4-1.8 microns for 30/70 weight ratio blend of polyethylene terephthalate/nylon-6.

Temperature in the molten blend is a variable which must be controlled within limits, to obtain the optimum spinning performance and yarn quality. The temperature should be near to that conventional for spinning nylon-6 alone, even though the polyester ingredient of the dispersions spun in the process of this invention will usually have a higher melting point than the nylon ingredient and the melt viscosity of the blend may be higher than in conventional nylon-6 spinning. For example, the blend melt viscosities can be 2000 or more poises at 275°C. Mixing and spinning temperatures of the melt for the present process are about 275°C. C±10°C. It should be appreciated that shearing action increases the polymer temperature, so the temperatures in the extruder walls should be correspondingly lower. Preferably about 260°C in the extruder metering zone. Therefore at very high shear it may be necessary to cool the extruder by a fan or equivalent means.

It is desirable especially when relatively high molecular weight, high viscosity nylon-6 (poly-caproamide) is the polyamide component, to maintain in the spinning tower (also called the quench stack) a relatively high temperature in the zone into which the filaments emerge from the spinneret, generally as disclosed in copending U.S. application of E. A. Swanson et al. Ser. No. 426,631 filed Jan. 19, 1963. In particular, temperatures measured at a distance of 1/4" from the outermost ring of filaments and 1/2" from the spinneret face are desirably in the range 310°C to 400°C.

A phenomenon common to melt spinning of linear polymers is the so-called "melt bulge" normally observed in the running molten filament about 1 mm below the outlet from the spinneret hole. The diameter of this bulge will exceed the diameter of the spinneret hole and will vary depending upon the polymer being spun, its viscosity, the jet velocity, the tension on the filament, and the geometry of the hole including the geometry of the entrance to the hole. This melt bulge is considered to be due to release of shear stress and pressure on the melt. With the resulting freedom for relieving strain along the polymer molecule, the molecules change shape, e.g. by coiling, folding, etc.

In the polymer blends as used in this invention, containing polyester dispersed in nylon, a melt bulge like that just described but much larger is observed about 1 cm below the spinneret face. This latter bulge typically has a diameter from about 0.6 mm. to about 1.7 mm. in polyethylene terephthalate/nylon-6 blends, varying with polyester proportions and the spinning conditions. It is this large bulge which is referred to hereinafter as the melt bulge.

If the filament is cut at a point where it is still molten, say about 3 inches below the large melt bulge, the molten filament will snap back like rubber, forming a 'blob' at the point where the melt bulge had about its maximum diameter.

It is observed in spinning the blends which are the subject of this invention that filament breaks tend to occur at or near the melt bulge. The tendency to break at that point probably arises from strains due to the changing flow pattern as the polymer passes into the zone of maximum melt bulge. If those strains can be reduced, minor inhomogeneities which would otherwise cause filament rupture and drips are harmless, and better spinning performance can be obtained.
Better flow and less strain at the melt bulge can be obtained, it is found (indicated by a reduction in maximum diameter of the melt bulge), by utilizing a generally conical entrance with relatively gradual convergence from the wide vertical shaft or counterbore into the spinneret capillary. These conical entrances should have an angle of convergence between elements at opposite sides of the cone, i.e., an apex angle, not exceeding about 60°. The sharper apex angles, in the range 15° to 30°, give better results but are more difficult to fabricate with the necessary precision and smoothness.

The ratio of length/diameter of the capillary should be 1.5 or greater, up to the limit imposed by the increase of pressure, required to force the polymer through a longer capillary at the desired jet velocity. A preferred range of ratios for capillary length/diameter is from about 2 to 5 using a capillary of about 6 to 22 mils diameter as is the practice in melt spinning of nylon-6. These capillaries can be round or may be slot-shaped, curved, triangular, square, crescent, cross-shaped, star-shaped, Y-shaped, etc. and/or can be grouped to produce partial coalescence of filaments to form various non-rounded cross sections. Holes forming hollow filaments can also be used. However, it will be appreciated that use of irregular shapes will affect the spinneret shears.

Under proper flow conditions in accordance with this invention the melt bulge diameter will not exceed at most 1.4 mm.; and in preferred operations is not over 1.2 mm. Relatively low viscosities, control of this parameter of melt flow into the spinneret capillary cooperates with high mixing shear in and beyond the extruder, i.e., with a critical fineness of the dispersion obtained, and with high spinneret shear and also with temperature maintained throughout the melt at 275±10° C.; to afford major benefits in spinning and drawing performance when all these 4 parameters are given their critical values.

The stated maximum melt bulge diameter of 1.4 mm. applies when round spinneret capillaries are used having relatively low diameters such as 8–14 mils. When capillaries of a larger diameter or of non-round shape are used, it is preferred to operate in accordance with limits upon the ratio of maximum melt bulge diameter: capillary diameter (i.e. the "die swell factor"). Accordingly, when using a capillary cross section having a longest dimension of 14 mils, or 0.35 mm., we believe the die swell factor above that die size should be not greater than 4; and this die swell factor of 4, it will be noted, corresponds to a melt bulge diameter of 1.4 mm. in a 14 mil die, and higher in larger dies. In using the smaller dies, it will be recognized, the permissible die swell factor will be greater than 4 since the permissible melt bulge of 1.4 mm. represents an increasingly large die swell factor, the smaller the die used.

After being extruded, usually into a heated zone as above mentioned, the filaments are carried downward into a cooling or quench zone which can be designed as for nylon spinning. Some tension is applied to the extruded filaments by the take-up rolls at the bottom of the quench stack, as usual in melt spinning of multifilament yarn. In spinning operations in accordance with this invention the take-up tension is kept at a low level, but sufficient to maintain smooth operation. Tension on the molten filament is produced by the action of the take-up rolls and by the weight of filament below the melt bulge, acting to attenuate the molten filament. The tension is related to the extent to which the filament is elongated in being taken up, and this in turn is proportional to the take-up speed divided by the jet velocity of the molten polymer stream. Higher jet velocities thus allow lower tension on the molten filament at given throughput and wind-up speeds; the higher jet velocities are also beneficial in reducing the diameter of the melt bulge. It has been found desirable in the procedure of this invention to utilize a stack draw down of at least 10 but not over 100 and a jet velocity of at least 25 feet/min.

The maximum jet velocity to be used depends on factors such as polymer viscosity, quench air flow, etc. and is limited by the fact that at excessive jet velocities the extruded filaments develop a melt bulge which intermittently varies in shape, producing irregularities in filament denier, etc. In operations in accordance with this invention the jet velocities ordinarily used do not exceed about 200 ft./min.

Particularly good results in spinning and drawing, and particularly high strength of the yarn are obtained when the polyamide component is polycaproamide terminated by a dicarboxylic acid as described in a pending U.S. application Ser. No. 426,632 filed Jan. 19, 1965; which polycaproamide has not over 10 m.eq. (milliequivalents) of primary amino groups per kg. (kilogram) of polyamide and has a formic acid relative viscosity (ASTM D-789—62T) in the range of about 40–65 (washed and dried) for 20–50 weight percent polyester and 40–100 FAV for polyester weight concentration below about 20%. These high viscosity polyamides have high melt viscosities in the range of about 600–3300 poises at 275° C. The process of this invention is not confined to use with such polyamides, how, but can be used to spin even polyamides having say 100 m.eq. end groups and more than 40 m.eq. of primary amino groups per kg. of polyamide.

When melt spinning is in accordance with this invention, the polyester ingredient of the dispersion can have relatively low viscosity. Polymers can be used which reduce the melt viscosity of the dispersion as compared to that of the nylon ingredient alone, e.g. polyethylene terephthalate with melt viscosity of 400 poises and reduced viscosity of 0.45 dl./mg. can be used. Polyester such as specifically polyethylene terephthalate having a reduced viscosity as low as 0.45 is marginal in utility for fiber formation when spun as such from the melt. The fact that such polyester is valuable for use in the process and product of the present invention may be connected with the fine diameter of fibril produced by the present process. Moreover, it may be of value to have a relatively fluid polyester so that it can easily be elongated in the melt.

The viscosity should nevertheless be adequate to permit "cold drawing" i.e. permanently elongating an undrawn filament of the polymer by drawing at a temperature below the polymer fusion temperature whereby the polymer generally develops a X-ray orientation along the filament axis. A minimum reduced viscosity for the polyester ingredient will usually be about 0.3 dl/gm.

To avoid polymer inhomogeneities arising from localized hydrolysis, the polyester and polyamide should have low and uniform moisture content, when subjected to melting, preferably not over 0.02% by weight moisture and particularly 0.01% by weight or less moisture.

The polymer blends will generally contain additives such as heat and/or light stabilizer, delustrant, pigment, antistat, lubricant, etc. appropriate to the intended end use, as employed in nylon or in polyester. The blends can also contain "bridging agents" to increase the wetting or dispersibility of polyester by nylon, whereby to facilitate forming and maintaining a dispersion of molten polyester particles in molten nylon.

The filaments of undrawn yarn produced in accordance with this invention will contain fine polyester fibrils dispersed therein, mainly lying lengthwise along the filament axis. In these undrawn filaments, the fibril lengths usually average about 20–100 microns and the fibril diameters average from about 0.04 micron to about 0.4 micron. These undrawn yarns are lubricated by the usual lube roll and wound into a package at the usual denier, e.g. about 4600 denier for undrawn 136-filament yarn. These undrawn yarns have low birefringence which will usually be in the range between about 0.002 and 0.004.

The undrawn yarns produced as above outlined can be drawn with or without heating while drawing, to impart molecular orientation along the filament axis, by
methods conventionally used for nylon yarns; and can be further treated, e.g., heat treated for relaxation of strains, coated with finishes, crimped, twisted and/or entangled, etc. by yarns used for nylon yarns whereby to adjust higher and lower the levels of shrinkage, creep, etc.; impart desired friction characteristics; impart bulk; improve runnability; etc.

The resulting yarns processed for high tenacity and high tensile modulus still have low flat spot index (creep). The yarns produced for high tenacity and high tensile modulus can be used for nylons whereby to adjust lower shrinkage, high abrasion resistance; high bulk resilience; and low water absorption “high” and “low” being relative to like yarn composed only of the nylon ingredient of the blend, as conventionally produced.

It is found that in the drawn yarns of this invention the polyester fibrils are greatly elongated and lie in the direction of the filament axis. In blends containing up to about 40/60 weight ratios of polyester:nylon, these fibrils are discrete polyester fibrils in the nylon matrix; whereas in compositions of this invention having higher polyester content, from about 40/60 to about 60/40 weight ratios with the polyester fibrils are interconnected to form a network within the nylon matrix and the remainder of the polyester is in the form of discrete fibrils in the nylon. As noted above under the heading “Tests,” these drawn polyester fibrils are too fine to be observed accurately with an optical microscope in cross section, but when the films are stained to heighten the contrast. The fibril diameters in the drawn yarn can be calculated as discussed under “ Definitions, Formulæ, and Tests” from the diameter of the polyester particles observed microscopically in the collected extrude and length of the fibrils in the undrawn yarn. Generally, the lengths of the fibrils in the 5× drawn yarn are in the range from 100 microns up to 500 microns or more.

The drawn yarns produced in accordance with this invention, containing polyester fibrils of diameters in the range from about 0.02−0.15 microns (the lower diameters corresponding to lower proportions of polyester in the total filament) have been found to have on the average at least 15,000 polyester fibrils per 1000 sq. microns of transverse area of the drawn filament; and at and below polyester/nylon weight proportions in the filament of 15/85, the number of polyester fibrils per 1000 sq. microns of transverse filament area, per this invention, is at least 30,000. These numbers have been observed as high as 250,000 and could go as high as 1,000,000. Again such counts have been checked within about 10% by electron microscopic observation. The filaments having the recited minimum numbers of fine fibrils, and especially those averaging at least about 40×10,000 per 1000 sq. microns of transverse area, are found to have high levels of tensile and elastic properties, especially high tensile modulus; and greatly improved fatigue properties as against yarns of like overall composition spun under conditions outside the limits of the invention. Such comparison yarns, drawn at 5× ratio, are found to have average numbers per unit transverse area, substantially lower than the minima found in yarns spun in accordance with this invention.

PREFERRED EMBODIMENTS OF THE INVENTION

The examples which follow are illustrative of this invention and of the best mode contemplated by the inventors of carrying it out but the invention is not to be interpreted as limited to all details of the examples.

In the laboratory operations, referred to herein, the extruder had screw diameter of one inch and depth of channel in the metering section of 0.031 inch. A throughput of about 1 to 5 pounds per hour was used through each spinneret. The spinnerets had 12, 20, or 24 holes each. In the pilot plant operations, spinning was like a full scale operation using an extruder having a 3¼ inch diameter screw and depth of channel in the metering section of 0.0938 inch. The throughput was generally 23.8 pounds of polymer per hour, for each 136 hole spinneret. quench stack combination. From one to four such spinnerets were fed by the one extruder in various runs.

In the laboratory runs, the residence time in the extruder and up to the spinneret was generally in the range of 4 to 10 minutes, and in the pilot plant the residence time in the extruder and up to the spinneret decreased from 8 to 2.5 minutes as the number of 136-hole spinnerets fed by the extruder increased from one to four.

During practice of this invention, it will be realized, certain conditions will normally be changed during the course of a run, at least in the large scale runs. For example, the extruder discharge pressure will be increased periodically during a run by increasing the rate of revolution of the screw, as material accumulates in the sand pack filters ahead of the spinneret and sometimes causes pressure build-ups through the sand pack under the conditions of constant throughput which are maintained. Accordingly, data listed for the particular examples below are averages of data taken under a given set of conditions, rather than being necessarily taken all in the same run. Generally, the examples, both laboratory and pilot plant, at given conditions represent several weeks of operation.

The headings in the tables of examples, identifying data, are explained in the preceding section of "Definitions, Formulæ, and Tests" or in footnotes to the tables. Data or complete examples labeled "Lab" in the tables were obtained on a scale of about 1 to 5 pounds per hour, as above indicated; the bulk of the data were obtained on the pilot plant scale of 23.8 pounds per hour per spinneret. It was verified that the laboratory data can validly be used for at least rough comparisons with pilot plant data. Where data may be limited those than the regular pilot plant data this is indicated by "c" or "d" or "..." in the tables.

Various operating conditions used in the examples are shown in the tables which follow. Conditions used in the examples are identified in the tables in the limit of the invention in one or more respects and are given for purposes of comparison with the examples of the invention, identified by numbers.

Conditions other than shown in the tables were as follows:

The quench stack used in the pilot plant runs of Table 1 below was as in Example 1 of Swanson et al. copending U.S. application Ser. No. 426,631 above cited, using a...
<table>
<thead>
<tr>
<th>Ex. A</th>
<th>Ex. B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drills per 1000 pounds</td>
<td>1,1</td>
</tr>
<tr>
<td>Breaks per 1000 pounds</td>
<td>9.8</td>
</tr>
<tr>
<td>Sum of drips and breaks</td>
<td>10.9</td>
</tr>
<tr>
<td>Draw ratio</td>
<td>4.9, 5.6</td>
</tr>
<tr>
<td>Avg. length of drawn fibers (microns)</td>
<td>289, 410</td>
</tr>
<tr>
<td>Avg. number (in 1000's) of fibers per 1,000 sq. microns of drawn filament traverse area</td>
<td>85, 122</td>
</tr>
<tr>
<td>UTS (gram/decimeter)</td>
<td>9.3, 9.3</td>
</tr>
<tr>
<td>UE (percent)</td>
<td>17.9, 17.9</td>
</tr>
<tr>
<td>Avg. length/diam. drawn fibers</td>
<td>13,000, 10,300</td>
</tr>
<tr>
<td>Toughness index (UTS/UE)*</td>
<td>38.4, 38.4</td>
</tr>
<tr>
<td>Initial tensile modulus (g/dl)</td>
<td>2.4, 4.0</td>
</tr>
<tr>
<td>Flat spot index</td>
<td>21, 31</td>
</tr>
<tr>
<td>Goodyear tube fatigue endurance (min.)</td>
<td>9, 400</td>
</tr>
<tr>
<td>Adhesion to rubber (lb.)</td>
<td>12, 12</td>
</tr>
<tr>
<td>Initial tensile modulus for hot wet yarn (g/dl)</td>
<td>13, 13</td>
</tr>
<tr>
<td>UTS for hot wet yarn (g/dl)</td>
<td>3.5, 4.0</td>
</tr>
</tbody>
</table>
flow of cooling gas countercurrent to the filament travel upward from the gas inlet, and below the gas inlet a main flow of gas cocurrent with the filament travel. The zone immediately below the spineret was heated and the gas therein was maintained essentially quiescent. In this zone the temperature was about 310° C.-390° C. at a point ½ inch below the spineret and ¼ inch outside the outermost ring of spineret holes. The laboratory stack was a smallerversion, without heating means.

The take-up speed was 1360 feet per minute for the standard throughput of 25.8 pounds per 136 holes. Undrawn denier was about 35–35 per filament. Birefringence of the undrawn yarn was in the range between 0.002 and 0.005.

The yarn was drawn in accordance with known procedures, either for maximum strength as desired in industrial yarns; or for high strength, and high uniformity as indicated by freedom from dye streaks and bands, as described in textile yarns. A heat relaxation or annealing step allowing about 5%–17% contraction of the drawn yarn was generally used in producing the textile yarns of the tables below, operated to adjust shrinkage to the desired levels as known in the art.

The solid polymers used, after blending as chips, were dried by vacuum and heat in the blender to bring the moisture content below 0.02% by weight. For industrial yarns the nylon ingredient contained a heat stabilizer, generally cupric chloride dihydrate at 50 parts per million of copper. For textile yarns, the nylon ingredient contained titanium dioxide defluorant at 0.5% by weight and manganese dichloride tetrahydrate light stabilizer at 20 parts per million of manganese.

The blending, transferring, and melting operations were conducted under a blanket of dry nitrogen (dew point not above 40° C.) with oxygen content not above 10 parts per million.

When yarns are produced in accordance with the invention, as will be seen from the examples, throughout the range of blends up to at least 60/40 by weight of polyester/nylon, the occurrence of drips is not over 15 and breaks is not over 30 and both combined are not over 40, per 1000 pounds of polymer spun. In the preferred yarn products of this invention, having when drawn 5X at least 30,000 polyester fibrils per 1000 sq. microns of transverse area, the properties attained at maximum draw are: UTS of at least 10 g./d.; toughness index of at least 40; initial tensile modulus of at least 60; flat spot index of at least 20; Goodyear tube fatigue endurance of at least 1500 minutes; and for the hot wet yarn (in water at 95° C.), initial tensile modulus of at least 40 g./d. and UTS of at least 6 g./d.

The preferred yarn products of the invention, when drawn and processed for textile uses rather than for maximum tenacity, still attain high initial tensile modulus of at least 60 g./d. and high wet tenile modulus of at least 40 g./d. as for the high tenacity yarns. They have dye strength, compared to nylon-6 as 100, of at least 150 tested with C.I. Disperse Blue 3, and dyeing uniformity rating of “Excellent.” Their liveliness, measured by percent work recovery is at least 65% compared to about 50% for nylon-6.

The total combination of the above yarn properties is found in certain yarn products of the invention, per the examples, especially in yarns spun from PET (polyethylene terephthalate)/nylon-6 blends containing about 25–40 parts by weight PET and correspondingly about 75–60 parts by weight nylon-6 wherein the nylon-6 has relative viscosity in aqueous 90% formic acid in the range of about 40–65 by ASTM Test D–789–62T, and has not over about 10 m.e.q. of primary amino groups per kg. of nylon and not over 80 m.e.q. of total end groups per kg. of nylon. The cited combination of attainable properties in this yarn is believed to be unique and of extraordinary consequence in offering a single yarn product which is of exceptional value for all of a wide range of end uses.

**TABLE I—PART B**

<table>
<thead>
<tr>
<th>Example number or letter</th>
<th>Ex. 8</th>
<th>Ex. 10</th>
<th>Ex. 12</th>
<th>Ex. 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating conditions:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyester, wt. proportion (and type)</td>
<td>1.000 (N2)</td>
<td>0</td>
<td>4.000 (E2)</td>
<td>4.000 (E3)</td>
</tr>
<tr>
<td>Nylon-6, wt. proportion (and type)</td>
<td>1.000 (N2)</td>
<td>96.014</td>
<td>96.014</td>
<td>60.014</td>
</tr>
<tr>
<td>Moisture content of blend</td>
<td>ca. 1,100</td>
<td>ca. 1,100</td>
<td>ca. 1,100</td>
<td>ca. 1,100</td>
</tr>
<tr>
<td>Apparent mixing shear in extruder (velocity gradient, sec.−1)</td>
<td>70</td>
<td>116</td>
<td>78</td>
<td>150</td>
</tr>
<tr>
<td>Extruder rev. per min.</td>
<td>35</td>
<td>99</td>
<td>40</td>
<td>77</td>
</tr>
<tr>
<td>Avg. diam. of polyester particles in extrudate (microns)</td>
<td>3.6</td>
<td>6.7</td>
<td>1.6</td>
<td>2.1</td>
</tr>
<tr>
<td>Avg. spinning temp. (° C. range=+3° C.)</td>
<td>265</td>
<td>210</td>
<td>220</td>
<td>270</td>
</tr>
<tr>
<td>Apparent spinnet capsule shear (1,000 sec.−1)</td>
<td>2.5</td>
<td>6.6</td>
<td>2.5</td>
<td>19.1</td>
</tr>
<tr>
<td>Spinnet capsule diam. (mil.)</td>
<td>22</td>
<td>13</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>Spinnet hole entrance apex angle ° (deg.)</td>
<td>(7)</td>
<td>(1)</td>
<td>(7)</td>
<td>(7)</td>
</tr>
<tr>
<td>Capillary length/diam.</td>
<td>0.6</td>
<td>0.6</td>
<td>0.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Mol. weight, max. diam. (mil.)</td>
<td>2.5</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Jet velocity (ft./min.)</td>
<td>28.5</td>
<td>54</td>
<td>54</td>
<td>110</td>
</tr>
<tr>
<td>Stack down</td>
<td>70</td>
<td>25</td>
<td>48</td>
<td>13</td>
</tr>
</tbody>
</table>

**Spinning and Drawing Results on Yarns Drawn and Processed**

for Textile Use (drawn for high level of both tenacity and dyeing uniformity)

| Drips per 1,000 pounds | 1 | 1.5 | 3 | 5 |
| Breaks per 1,000 pounds | 4 | 5 | 20 | 5 |
| Sum of drips and breaks | 5 | 7 | 23 | 8 |
| Draw ratio | 3.0 | 8.4 | 8.4 | 8.4 |
| Avg. length of drawn fibrils (microns) | 215 | 71 | 380 | 380 |
| Avg. number in 1,000 sq. microns of drawn filament travers area | 109 | 13.2 | 47 | 44.5 |
| UTS (gram/denier) | 4.8 | 6.0 | 8.8 | 7.4 |
| UTE (percent) | 46 | 60 | 65 | |
| Initial tensile modulus (gr./den. | 32 | 44 | 38 | 66 |
| Avg. length/diam. drawn fibrils | 10,750 | 1,195 | 4,230 | 1,920 |
| Initial tensile modulus for hot wet yarn (g./den.) | 15 | 28 | 49 | 66 |

See footnotes at end of table.
TABLE I—PART B—Continued

<table>
<thead>
<tr>
<th>Example number or letter</th>
<th>Ex. F 1</th>
<th>Ex. F 2</th>
<th>Ex. F 3</th>
<th>Ex. F 4</th>
<th>Ex. F 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>UT8 for hot wet yarn (g/d)</td>
<td>3.0</td>
<td>3.8</td>
<td>3.5</td>
<td>5.2</td>
<td>5.8</td>
</tr>
<tr>
<td>Dye strength (vs. Nylon-6)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Dyeing uniformity (rating)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Work recovery (percent) (lab)</td>
<td>61</td>
<td>55</td>
<td>55</td>
<td>73</td>
<td>73</td>
</tr>
</tbody>
</table>

1 See Table A below:

# TABLE A

(1) Polyethylene terephthalate properties

<table>
<thead>
<tr>
<th>Type</th>
<th>End groups (m.e.q./g)</th>
<th>Reduced viscosity (25°C, g/100mL)</th>
<th>Melt viscosity (25°C, 1000g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>60</td>
<td>125</td>
<td>0.45</td>
</tr>
<tr>
<td>E2</td>
<td>56</td>
<td>71</td>
<td>0.6</td>
</tr>
<tr>
<td>E3</td>
<td>48</td>
<td>55</td>
<td>0.8</td>
</tr>
<tr>
<td>E4</td>
<td>22</td>
<td>69</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Note:** For all the PET's, glass transition temperature is about 88°C by DTA.*

(2) Nylon-6 properties

<table>
<thead>
<tr>
<th>Type</th>
<th>End groups (m.e.q./g)</th>
<th>Reduced viscosity (25°C, g/100mL)</th>
<th>Melt viscosity (25°C, 1000g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>125</td>
<td>60</td>
<td>0.8</td>
</tr>
<tr>
<td>N2</td>
<td>75</td>
<td>56</td>
<td>1.08</td>
</tr>
<tr>
<td>N3</td>
<td>62</td>
<td>64</td>
<td>1.12</td>
</tr>
<tr>
<td>N4</td>
<td>56</td>
<td>83</td>
<td>1.38</td>
</tr>
<tr>
<td>N5</td>
<td>49</td>
<td>85</td>
<td>1.65</td>
</tr>
</tbody>
</table>

* End groups and Tg by the procedures of the above-mentioned Twikeyson application, Ref. No. 360,024.

**Ref. visc.** Relative viscosity in aqueous 90% formic acid by AST Test 17-780-676.

* DTA—Differential thermal analysis.

# TIRES FROM PREFERRED YARN OF THE INVENTION

Standard 750 x 14 2-ply tires were produced by the procedure of Example 2 of the copending U.S. application of C. W. Beringer, Ser. No. 478,215, filed July 19, 1965, for "Reinforcing Cord and Tire Therefrom," using 1260 denier, 204 filament yarn spun at throughput of 38.7 lb./hr. through a 204 hole spinneret under the conditions of Example 4 above. These tires were compared against tires similarly produced from commercial nylon-6 yarn in the commercially most important properties, with the results shown in the table below:

(1) Time (seconds) at 30 m.p.h. to non-objectionable flat spot, per panel jury. This invention: 36 sec.; Comparison: 60 sec.

(2) Durability test (miles to failure per Government Services Administration test, Bull. ZZ--T--0038LJ of July 13, 1959, modified by a final 80% overload stage).

**Test sequence**

(a) Inflate to 24 p.s.i. (abs.) at ambient temperature;
(b) Run 420 miles under full load (1020 lb.) at 60 m.p.h. (7 hrs.); then
(c) Run 960 miles under 1204 lb. (20% overload), 60 m.p.h. (16 hrs.); then
(d) Run 1440 miles under 1408 lb. (40% overload), 60 m.p.h. (24 hrs.); then
(e) Inflate to 45 p.s.i.g. and run under 1816 lb. (80% overload), 45 m.p.h. to failure.

Results (hours under 80% overload at 45 m.p.h., to failure): This invention: 33 hrs.; comparison: 3 hrs.

# SEAT BELTS FROM PREFERRED YARN OF THE INVENTION

2" automotive seat belts were woven by a standard procedure from yarn of Example 3 above and compared against seat belts similarly woven from (A) commercial nylon-6 yarn and (B) yarn of Example B above. The following table shows the results of the comparison in important properties for seat belts.

(1) Elongation: 2500 lb. stress; This invention 16.5%; vs. (A) 20.2% (B), 17.8%.

(2) Elongation: 3000 lb. stress; This invention: 18%; vs. (A) 22%; (B) 19.3%.

(3) Breaking strength: This invention: 7200 lb.; vs. (A) 6640 lb., (B) 6530 lb.

(4) Breaking strength retained after 2500 cycles in Society of Automotive Engineers (SAE) Test by abrasion. This invention: 75%; vs. (A) 63%, (B) 55%.

(5) Breaking strength retained after 5000 cycles on bar abrader: This invention: 83%; vs. (A) 85%, (B) 75%.

(6) Dyeability (CI) Disperse Blue 3: This invention: Excellent; vs. (A) Good, (B) Good.

It will be seen that the seat belts from yarn of this invention have desirable level of elongation coupled with very high breaking strength and high retention of breaking strength after being flexed or abraded; and have at the same time excellent dyeability.

Table II below illustrates, in Examples 14–18, yarns produced by the small scale procedure above outlined, under the conditions indicated in the table and using the variants of the polyester and nylon ingredients indicated in the table. As seen from the table, the yarn products of these examples showed improved properties over the nylon-6 control generally as for the yarns of Table I.
The invention claimed is:

1. A process for melt spinning, to form continuous filament yarn, a dispersion of polyester in polylamide, which polyester contains from 1 to 2 rings in the repeating unit of the main polymer chain, the polyester ingredient and the polylamide ingredient each being capable of being formed into a filament which can be cold drawn whereby at least the polylamide ingredient displays, by X-ray, orientation along the filament axis; which process comprises:

(a) subjecting a molten mixture of said polyester and polylamide to mixing shear which brings the average diameter of the polyester particles dispersed in the polylamide to a value D in microns given by the relation:

$$D = 0.04P + 0.4C + 0.25$$

where P is the parts by weight of the minor ingredient of the blend, based on the polyester/polyamide mixture is 100, and C is the number of rings in the polyester ingredient.

(b) flowing the resulting molten dispersion through each spinneret capillary at apparent shear having a velocity gradient of at least 3,000 reciprocal seconds; and

(c) maintaining in the melt, from the exit of the mixing zone up to the spinneret, a temperature in the range 275° C. ±10° C.

2. The process of claim 1 wherein the molten dispersion is advanced through each spinneret hole in a gradually converging stream which produces in the molten extruded filament a diameter of the melt bulge not exceeding about 1.4 mm.; the jet velocity is in the range between 25 ft./min.; and the stack draw-down is in the range between 10 and 100.

3. The process of claim 2 wherein the molten mixture of polyester and polylamide is subjected to an apparent mixing shear of at least 100 reciprocal seconds and is subjected to an apparent shear in the range between 5,000 and 30,000 reciprocal seconds; and the molten dispersion is flowed through spinneret holes having a conical entrance to the capillary whereby the apex angle does not exceed about 60°.

4. Process of claim 2 wherein the polyester ingredient is predominantly polyethylene terephthalate and the nylon ingredient is predominantly poly-ε-caprolactam; the value of D in microns is given by the relation

$$D = 0.04P + 0.4C + 0.25$$

diameter of the melt bulge in the molten extruded filament is not above 1.4 mm.; and the jet velocity is in the range between 25 ft./min.; and the stack draw-down is in the range between 10 and 100.

5. The process of claim 3 wherein the polylamide ingredient is dried at a moisture content below 0.2% by weight.

6. The method of claim 1 wherein the polylamide has a relative viscosity above about 30.

7. The method of claim 6 wherein said polylamide has a relative viscosity between about 30 and 83.

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JAY H. WOO, Primary Examiner

U.S. Cl. X.R.

260—857; 264—176 F