Nov. 10, 1970 TAKAAKI FUKUSHIMA ET AL 3,539,680

PROCESS AND APPARATUS FOR DRAWING POLYESTER FILAMENTS

Filed Aug. 7, 1967 2 Sheets-Sheet 1

Fig. 2

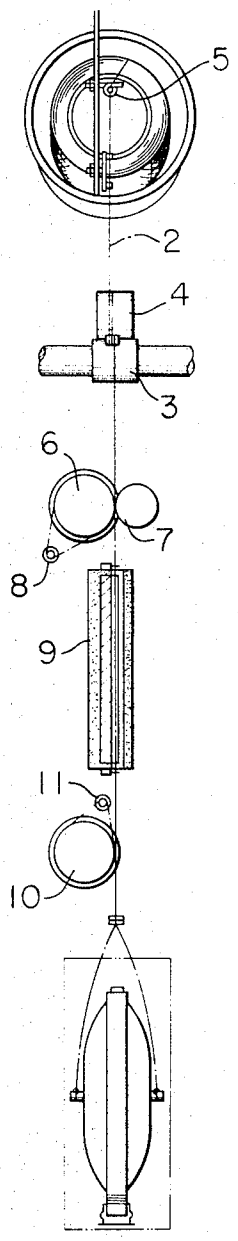


Fig. 1

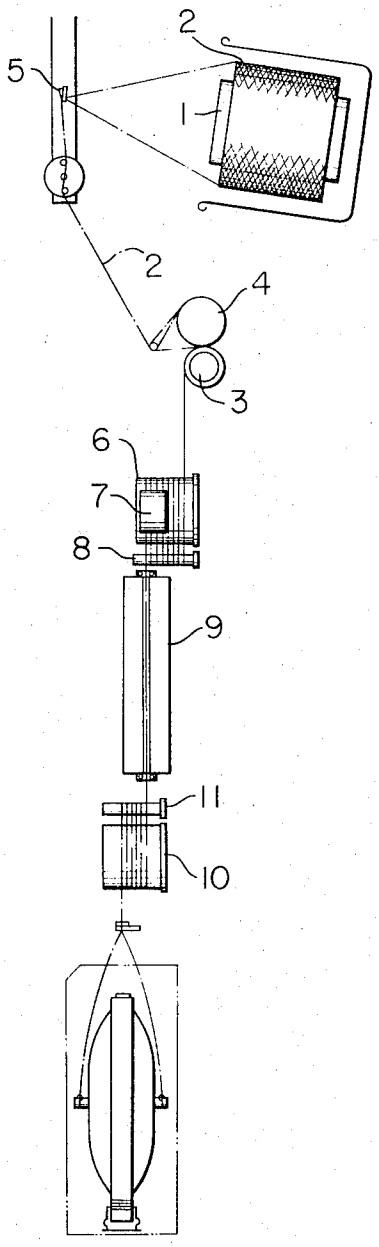


Fig. 3

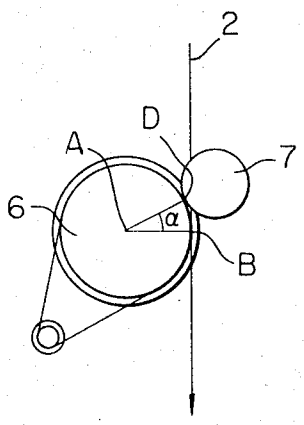
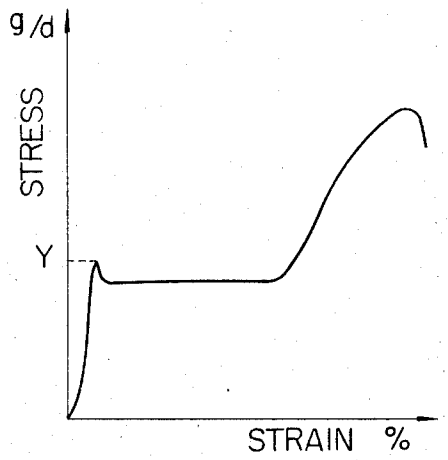


Fig. 4



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3,539,680

PROCESS AND APPARATUS FOR DRAWING POLYESTER FILAMENTS

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U.S. Cl. 264—290 10 Claims

ABSTRACT OF THE DISCLOSURE

A drawing process wherein fixation of the necking point is made certain by drawing undrawn polyester filaments while pressing the same onto a feed roller by a pressure roller provided at the side in contact with the feed roller heated at a predetermined temperature and said process is of non-friction type and an apparatus therefor.

The present invention relates to improved process and apparatus for drawing polyester filaments. More particularly, the present invention relates to a drawing apparatus wherein a heated roller and a pressure roller are positioned in novel correlated positions with respect to the drawing direction of the filaments and a novel drawing process for preparing polyester filaments having few fluffs and uniform dyeability.

Heretofore, upon drawing polyester filaments a process for continuous drawing which comprises providing a hot pin fixed between two rollers having different peripheral speeds, wrapping undrawn filaments around said hot pin by a desired number of times to impart heat necessary for drawing, at the same time, to fix a necking point by frictional resistance by the passage of the undrawn filaments run on said hot pin has been employed.

However, such a prior drawing process suffers certain disadvantages. In particular when high drawing speeds are used and when the total denier of the undrawn filaments is large, a large number of wraps around the hot pin is required in order to impart sufficient heat to the filaments necessary for drawing. However, due to frictional resistance of the pin, there is a limit to the number of wraps that can be provided around the pin. Further, there has been the disadvantage that friction can cause undesirable properties in the filaments. In particular, the necking point tends not to be fixed, but fluctuates thus causing fluffs and unevenness in dyeing. Further, abrasion of the hot pin per se readily takes place with the result that the pin has to be renewed at intervals.

On the other hand, there has been a drawing process not using a hot pin, but using a heated roller. However, in this case also, it was not possible to prevent fluctuation of the necking point.

An object of the present invention is to provide novel drawing process and apparatus having improved the aforementioned various defects in prior arts.

Other objects of the present invention will become apparent from the following description.

It has been found that these objects of the present invention can be achieved by a process for drawing a bundle of undrawn thermoplastic saturated linear polyester filament having a filament denier below 150 and containing at least 80 mol percent of ethylene terephthalate units, which comprises passing said undrawn filaments in a plurality of wraps around a positively rotated heated feed roller which cooperates with a freely rotatable pressure roller and from the feed roller to a draw roller which is rotating at a peripheral speed which is higher than the peripheral speed of the feed roller to thereby draw the filaments to 2.0–6.0 times its original length, the pressure roller having an elastic outer surface and being arranged so that at least the last wrap of the filament around the feed roller is pressed into contact with the outer surface of the feed roller, the point of contact being such that an angle α formed by a radius connecting the point where the filaments would depart from the feed roller if the pressure roller were not used with the center of the feed roller and a radius connecting the said point of contact with the center of the feed roller does not exceed 20°, the surface temperature (T° C.) of the heated feed roller being within the range of the second order translation point of the undrawn filaments (T_g° C.) to a temperature 55° C. higher than the said second order transition point with the contact time of the undrawn filaments with the heated feed roller (t sec.) satisfying the equation:

$$-0.120(T-T_g)+28.420 \geqq t \geqq -0.003(T-T_g)+0.189$$

According to the present invention there is also provided an apparatus for drawing a bundle of undrawn thermoplastic saturated linear polyester filaments having a filament denier below 150 and containing at least 80 mol percent of ethylene terephthalate units, which comprises a positively rotatable feed roller which is adapted to heat undrawn filaments wound around the outer surface thereof and advance the heated fibers at a predetermined speed, means for imparting a pre-tension to the undrawn filaments before they are wound around the feed roller, a positively rotatable draw roller adapted to rotate at a peripheral speed which is higher than the peripheral speed of the feed roller for withdrawing the heated filaments from the feed roller and a freely rotatable pressure roller having an elastic outer surface and contacting the outer surface of the feed roller so that at least the last wrap of undrawn filaments is pressed into contact with the outer surface of the feed roller, the point of contact being such that an angle α formed by a radius connecting the center of the feed roller and the said point of contact and a radius connecting the center of the roller with the point where filaments would depart from the feed roller if the pressure roller were not used does not exceed 20°.

Novel features of the present invention will be easily understood from consideration of the following description together with the accompanying drawings showing one embodiment of the apparatus used for the present invention.

FIG. 1 is a front elevation of the apparatus. FIG. 2 is a side elevation of the apparatus. FIG. 3 is an enlarged view for showing more clearly relative positions of the heated feed roller and the pressure roller shown in FIG. 2. FIG. 4 is a stress-strain curve of undrawn filaments measured by an Instron tensile tester.

In FIG. 1, undrawn filaments 2 are wound about a bobbin 1, 3 is a delivery roller rotating at a predetermined speed, rotating integrally with a nip roller 4 located thereabove, withdrawing the undrawn filaments 2

via a guide 5, 6 is a cylindrical heated feed roller mounted on a rotary shaft (not shown), accommodating inside the roller a heating member (not shown) to maintain a predetermined temperature. The heated feed roller 6 rotates at a surface speed slightly faster than that of the delivery roller 3, thereby imparting necessary pre-tension to the filaments. In the vicinity of the heated feed roller 6, a separator roller 8 is mounted and the filaments are wrapped around the heated feed roller 6 and separator roller 8 by a necessary number of times for heating the filaments and preventing them from slipping; 7 is a pressure roller rotating while being pressed onto the surface of the heated feed roller 6, pressing either several wraps of filaments containing at least the last wrap of filaments about to depart from the heated feed roller or only the last wrap onto the heated feed roller thereby the necking point is definitely fixed to the contact point of the two rollers without fluctuation. Under the heated feed roller 6, a slit heater 9 is provided, and further thereunder a drawing roller 10 and a separator roller 11 for the drawing roller are provided. The filaments are pulled by the drawing roller 10 and drawn. The drawn filaments are heat-treated by the slit heater 9 if necessary.

In practicing the process of the present invention, it is necessary that surface temperature (T° C.) of the heated feed roller should be within the range of T_g° C. to (T_g+55)° C. where T_g° C. is second order transition point of the undrawn filaments. When T° C. becomes lower than T_g° C., heat necessary for drawing is not imparted to the undrawn filaments, and as a result, dyeing unevenness is brought about in the drawn filaments. When T becomes higher than (T_g+55)° C., the undrawn filaments stick to one another by fusing and crystallize partially, then drawing all the filaments without any breaking becomes difficult. A preferable range of T is from (T_g+5)° C. to (T_g+25)° C.

The time (t, second) that the filaments must contact with the heated feed roller in order that they receive satisfactory heating differs naturally depending upon the surface temperature (T° C.) of the heated feed roller; however t should satisfy the following equation:

$$-0.120(T-T_g)+28.420 \geqq t \geqq -0.003(T-T_g)+0.189$$

and the filaments must be wrapped around the heated feed roller 6 for a time satisfying said formula. A preferable range of t is

$$-0.120(T-T_g)+7.72 \geqq t \geqq -0.003(T-T_g)+0.189$$

The most novel and important feature in the process of the present invention is the position of contact point where the pressure roller contacts with the surface of the heated feed roller shown in FIG. 2. Referring now to FIG. 3 which is an enlarged view of this portion, the position of the contact point is such that an angle α formed by a radius connecting a point B where the filaments would depart from the heated feed roller if the pressure roller were absent or in an inoperative position, with the center A of the heated feed roller and a radius connecting the contact point D with center A does not exceed 20° C.

When said angle α measured in the opposite direction of proceeding of the filaments exceeds 20°, because an inclination that the necking point fluctuates on the surface of arc BD of the heated feed roller increases, drawing is apt to become non-uniform and because the distance the drawn filaments contact the heated feed roller increases, due to the difference of the peripheral speed of the heated feed roller from the speed of the drawn filaments running on said roller, occurrence of fluffs is caused.

On the other hand, when said angle α measured in the direction of proceeding of the filaments exceeds 20°, the drawn filaments get in contact with the pressure roller, not with the feed roller. Since the elastic material covering the surface of the pressure roller has a relatively low hardness, the contact results in damage to the surface of the pressure roller which in turn causes fluffs to occur and further increases the chances of filament breakage. At the same time, it becomes necessary to frequently replace the pressure roller. Further, the necking point will again fluctuate with the result that drawing becomes non-uniform, causing dyeing unevenness and the formation of fluffs.

A preferable range of angle α is 0° to 3°. By so doing, friction harmful to the filaments is minimized while maintaining sufficient heating and certain fixation of the necking point, as a result an excellent functional effect that makes it possible to carry out drawing at a high speed can be obtained.

A draw ratio which can be adopted in the process of the present invention is 2.0–6.0 and a drawing speed adoptable in the present invention is 50 m./min.–4500 m./min., namely, an operation at a draw ratio and a drawing speed higher than those normally adopted is possible in the present invention.

Further, as one embodiment for preferably practising the process of the present invention, by a process wherein before the undrawn filaments pass around the heated feed roller, by imparting a pre-determined pre-tension within the range of 10–90% of the tension at which the neck occurs (Y) shown in a stress-strain curve of said undrawn filaments measured by an Instron tensile tester under conditions of at 20° C. temperature and 65% relative humidity shown in FIG. 4, said filaments without substantial drawing are fed to the heated feed roller.

According to experimental results, when this pre-tension is less than 10% of the tension at which the neck occurs it becomes difficult to maintain the tension in the undrawn filaments at a predetermined value. On the other hand, when it becomes more than 90% of said tension, local drawing is carried out to bring about dyeing unevenness and occurrence of fluffs. Therefore, it is preferable that this pre-tension is within the range of 10–90% of the tension at which the neck occurs.

Heretofore as an apparatus to impart these pre-tensions, there have been a thread brake and a guide. However, it is difficult for them to impart uniform and predetermined tension to filaments.

In the present invention, in which the undrawn filaments are wrapped around the heated feed roller, in order to minimize occurrence of fluffs and dyeing unevenness, it is especially required to feed said filaments under a predetermined tension. Therefore, it is essentially preferable to securely hold and withdraw the filaments by using combination a of a nip roller and a delivery roller as shown in FIG. 1. In order to impart a preferable pre-tension as mentioned above, ratio of peripheral speeds of the delivery roller to the heated feed roller is generally within the range of 1:1.001–1:1.030. However, a thread brake or a guide may be used, if it can impart uniform and predetermined tension.

In the apparatus used in the present invention, as a method of the urging of pressure roller into contact with the heated feed roller, a normal method using a spring, compressed air and oil pressure may be adopted.

By these means, the pressure roller is pressed onto the heated feed roller in such manner as the necking point of th undrawn filaments may be fixed.

The peripheral surface of the pressure roller is made of an elastic material such as rubber, and the surface hardness of said elastic material, as measured by JIS (Japanese Industrial Standard) K–6301, is preferably 30–95.

The surface of the heated feed roller may be a flat face, however, it may be a mat face.

As means for heating the heated feed roller, a normal heating means by electricity, steam, hot air, heated medium and infrared radiation may be adopted. Further, the heating may be effected from inside the roller, and the sealed surrounding space of the roller may be heated.

As means for heat treating the drawn filaments optionally provided between the heated feed roller and the draw-

ing roller an apparatus normally used for heat setting a fiber such as heat plate and slit heater may be adopted. However, in view of the object of the present invention of trying to impart to the filaments as little friction as possible throughout the drawing step, use of a slit heater is most preferable.

As conditions for heat setting, a temperature of 120°–300° C. and a time of 0.01–2 seconds may be adopted.

Polyester filaments used in the present invention contain not less than 80 mol percent of ethylene terephthalate unit, and as other acid component, a dibasic acid such as phthalic acid, isophthalic acid, adipic acid, oxalic acid, sebacic acid, suberic acid, glutaric acid, pimelic acid, fumaric acid and succinic acid may be used. A polymerization degree modifier like propionic acid may be contained. As alcohol component, a divalent alcohol such as polymethylene glycol having 2–10 carbon atoms (trimethylene glycol and butylene glycol) and cyclohexane dimethanol may be cited. And they may contain a small amount of the following compound as a modifier, 5-oxydimethyl isophthalate, 5-oxydimethyl hexahydroisophthalate, benzene-1,3,5-tricarboxylic acid, para-carbomethoxy phenyl diethyl phosphonate, 3,5-dicarboxy phenyl diethyl phosphonate, pentaerythritol, glycerol, glucose, phosphoric acid, triphenyl phosphate, tri-p-carbomethoxy phenyl phosphate, triphenyl phosphinate, triphenyl arsenite, tricapryl borate, sorbitan, trimesic acid and diethylene glycol.

Also, a small amount of another polymer such as polycarbonate, polyamide (such as nylon 6 or nylon 66), polyurethane and polyolefin, may be contained.

Although this invention may be applied to various polyesters described above, it is especially suitable for the drawing of filaments composed of polyethylene terephthalate alone.

The polyester filaments used in the present invention are filaments whose denier per monofilament is below 150 and a birefringence of undrawn filaments is within the range of 0.0005 to 0.0150. Undrawn filaments whose intrinsic viscosity $[\eta]$ is 0.3–1.2 may be used.

In the conventional drawing process, when undrawn filaments whose $[\eta]$ is below 0.5 are drawn, fluffs are brought about and satisfactory drawing could not be carried out. However, by the process of the present invention, it becomes possible to carry out satisfactory drawing of undrawn filaments whose $[\eta]$ is below 0.5. Polyester fiber having such a low $[\eta]$ value is valuable as a fiber improved in occurrence of pilling a common defect of a normal polyester fiber.

The cross sectional configuration of polyester filaments usable in the present invention may be normal circular, non-circular (triangular, pentagonal, flat, cross, etc.), hollow (doughnut, non-circular hollow). Especially when filaments having non-circular or non-circular hollow cross sectional configurations are drawn by the conventional drawing process, fluffs and dyeing unevenness increase, however, according to the process of the present invention, it is possible to carry out drawing of such filaments without being accompanied by such shortcomings.

Explanations will be made hereinbelow about measuring methods described in the explanations of examples to be mentioned later.

(a) Measuring method of a second order transition point (T_g): Tg is defined by A. Pace in U.S. Pat. specification No. 2,556,295 and measuring was carried out by a Volume Dilatometry method reported by Bekkedahl (J. Research N.B.S., 42, 145 (1949)). In the case of non-crystalline undrawn polyethylene terephthalate filaments, T_g is 69° C.

(b) Measuring method of an intrinsic viscosity $[\eta]$, In o-chlorophenol 1.25% of the sample was dissolved at 100° C., specific viscosity $[\eta_{sp}]$ of the obtained solution was measured at 35° C. and $[\eta]$ was sought from

$$[\eta]=\lim_{c\to 0}\frac{\eta_{sp}}{c}$$

(c) Measuring method of a birefringence (Δn): It was measured by using a polarisation microscope having a crossed nickel prism reported by A.N.J. Hein in Text. Research J., 22, 513 (1952).

(d) Measuring method of dyeing unevenness: A sample was knitted, and a knitted test piece was dyed in a solution containing 3% of a dyestuff (Dispersed Scarlet B) based on said test piece by boiling at 100° C. for 90 minutes. Dyeing unevenness of the dyed knitted test piece was adjudicated by naked eyes and the result was converted to N.B.S. unit. Relationship of N.B.S. unit with adjudication by naked eyes is as follows.

N.B.S.	Adjudication by naked eyes
0.0–0.5	Trace.
0.1–1.5	Slight.
1.5–3.0	Noticeable.
3.0–6.0	Appreciable.
6.0–12.0	Much.
Above 12.0	Very much.

(e) Measuring method of stress unevenness of drawn filaments: It was measured by an Elasticity Meter Dynagraph II manufactured by Herbert Stein Co. A sample was caused to run at a measured speed of 24 m./min. and a draw ratio of 10% and variation of stress at that time was measured continuously. Difference of maximum stress from minimum stress at a sample filaent length of 8 m. was R, which was continuously measured for 10 times (measured for 3 m.×10=80 m. continuously).

Stress unevenness means an average value ($\overline{R}$) of the so obtained R's

$$\left(\overline{R}=\sum_{i=1}^{10} Ri/10\right)$$

The number of wraps of the filaments about the heated feed roller—7

Contact time of the filament with the heated feed roller—0.775 second

Temperature of the portion of the slit heater were filaments pass—240° C.

Properties of the obtained drawn heat-set filaments were as shown in the following Table 1.

(f) Measuring method of fluffs of drawn filaments: Number of fluffs per 1,000,000 m. of drawn filaments was measured.

Now, the present invention will be explained with reference to the following examples, however, the present invention will not be limited thereby.

EXAMPLES 1–4

Controls 1–2

Polyethylene terephthalate chips having an intrinsic viscosity (η) of 0.65 were melted at 288° C., extruded through a spinneret having orifices of diameters of 0.25 mm., wound at a speed of 930 m./inm. to become undrawn filaments whose total denier was 261.

This undrawn filaments had an intrinsic viscosity (η) of 0.63, a second order transition point (T_g) of 69° C., a birefringence (Δn) of 549×10^{-5} and tension at which the neck occurs of 0.36 g./d.

This undrawn filaments were drawn and heat-set by using the drawing apparatus shown in FIGS. 1 and 2 while varying the surface temperature of the heated feed roller under the following conditions.

Pre-tension—0.10 g./d.

Draw ratio—3.67

Drawing speed—500 m./min.

Diameter of the heated feed roller—100 mm.

TABLE 1

	Surface temp. of the heated roller (° C.)	Tenacity, g./d.	Elongation, percent	Dyeing unevenness	Stress unevenness	Fluffs per 1,000,000 m.
Control 1	65	4.78	26.4	10.0	36.2	1.2
Example 1	70	4.93	27.3	1.5	9.0	0.4
Example 2	80	5.03	27.5	0.0	8.3	0.2
Example 3	100	5.01	27.2	1.0	9.2	0.7
Example 4	120	4.98	27.9	2.0	13.4	1.0
Control 2	125	4.92	28.0	2.0	14.0	4.2

In Control 1 wherein the surface temperature of the heated feed roller was too low, values of dyeing unevenness and stress unevenness became very large, which showed uniform drawing was not carried out. In Control 2 wherein said surface temperature was too high, occurrence of fluffs was high.

EXAMPLES 5–10

Controls 3–5

The undrawn filaments same as in Examples 1–4 were drawn and heat set by using the apparatus shown in FIGS. 1 and 2 while varying drawing speed and the number of wraps of filaments around the heated feed roller under the following conditions.

Pre-tension—0.10 g./d.
Draw ratio—3.67
Diameter of the heated feed roller—100 mm.
Surface temperature of the heated feed roller—85° C.
Temperature of the portion in the slit heater—240° C.

Properties of the obtained drawn heat-set filaments were as shown in Table 2.

TABLE 2

	Number of wraps	Drawing speed, m./min.	Contact time with the heated feed roller, sec.	Tenacity, g./d.	Elongation, percent	Dyeing unevenness	Stress unevenness	Fluffs per 1,000,000 m.
Control 3	7	12	32.2	4.98	27.8	1.5	8.1	5.9
Example 5	7	64	6.1	5.10	26.4	1.0	7.7	2.3
Example 6	7	80	4.8	5.03	27.1	0.5	8.0	0.6
Example 7	7	640	0.45	5.09	27.0	0.0	8.4	0.3
Example 8	7	2560	0.15	5.08	27.3	0.5	8.8	0.7
Control 4	7	2880	0.13	5.14	26.9	5.0	24.6	2.8
Control 5	1	500	0.11	4.83	26.8	5.0	23.5	3.2
Example 9	2	500	0.22	5.03	27.3	0.5	9.3	1.1
Example 10	8	500	0.88	5.05	27.5	0.0	8.0	0.2

The control time of undrawn filaments with the heated feed roller necessary for practising the process of the present invention obtained by calculation based on experimental conditions is within the range of 26.50 to 0.14 seconds, and the Controls 3, 4 and 5 wherein said contact times were outside this range, then dyeing uneveness and fluffs were much.

EXAMPLES 11–15

Controls 6–8

The undrawn filaments same as those in Examples 1–4 were drawn and heat-set under conditions same as in Examples 1–4 except the temperature of the heated feed roller was 85° C. and varying the angle by shifting the pressure roller upstream or downwardly downstream. Properties of the obtained drawn, heat-set filaments were as shown in Table 3 below.

TABLE 3

	Angle α	Tenacity, g./d.	Elongation, percent	Dyeing unevenness	Stress unevenness	Fluffs pr. 1,000,000 me
Control 6	Upstream 30°	5.08	28.0	0.5	9.2	4.8
Example 11	Upstream 20°	5.01	27.5	0.5	8.5	1.2
Example 12	Upstream 10°	5.09	27.1	0.0	8.7	0.8
Example 13	0°	5.12	28.3	0.0	8.4	0.2
Example 14	Downstream 10°	5.02	27.8	0.5	8.2	0.4
Example 15	Downstream 20°	5.10	26.9	0.5	9.6	0.6
Control 7	Downstream 30°	5.04	27.5	0.5	8.9	1.8
Control 8	Without a pressure roller	5.08	27.0	0.5	16.7	1.2

When the angle α exceeded 20° upwardly or downwardly number of fluffs increased. In Control 7 wherein the angle α exceeded 20° downwardly the pressure roller was apt to be hurt and it became necessary to replace the pressure roller after it was used for only 2 hours.

Controls 9–26

The undrawn filaments same as those of Examples 1–4 were drawn and heat-set in accordance with the conventional drawing process using a hot pin under the following conditions.

Pre-tension—0.10 g./d.
Draw ratio—3.67%
Drawing speed—500 m./min.
Diameter of a (mat faced) drawing pin—60 mm.

The number of wraps filament around the drawing pin—2 times

Temperature of the portion in the slit heater where filament pass—240° C.

Properties of the obtained drawn, heat-set filaments were as shown in Table 4 below.

TABLE 4

	Pin temp., ° C.	Tenacity, g./d.	Elongation, percent	Dyeing uneven-ness	Stress uneven-ness	Fluffs per 1,000,000 m.
Control 9	65	4.86	30.1	12.0	54.2	1.3
Control 10	70	5.11	27.0	10.0	55.6	1.5
Control 11	80	5.03	27.9	8.0	46.7	0.9
Control 12	100	4.91	29.2	10.0	48.9	1.2
Control 13	120	5.14	26.5	10.0	58.2	0.8
Control 14	125	4.99	28.9	10.0	53.4	1.4

Drawing were carried out under the same conditions as mentioned above, except making the pin temperature 85° C. and varying drawing speed. Properties of the obtained drawn, heat-set filaments were as shown in Table 5 below.

TABLE 5

	Drawing speed, m./min.	Contact time with the pin, sec.	Tenacity, g./d.	Elongation, percent	Dyeing uneven-ness	Stress uneven-ness	Fluffs per 1,000,000 m.
Control 15	2.6	32.2	5.06	29.3	1.5	9.8	6.3
Control 16	13.8	6.1	5.21	28.2	2.0	12.5	1.8
Control 17	17.3	4.8	5.10	29.5	2.0	13.8	0.9
Control 18	185	0.45	4.97	27.8	2.0	18.4	0.4
Control 19	553	0.15	5.09	29.1	10.0	64.6	1.4
Control 20	629	0.13	4.85	29.6	12.0	88.7	18.1
Control 21	12	6.92	5.18	26.5	3.0	25.3	0.2
Control 22	64	1.30	5.09	26.2	4.0	32.6	0.9
Control 23	80	1.04	5.11	27.4	4.0	37.4	0.7
Control 24	640	0.13	4.96	26.8	12.0	62.8	16.7
Control 25	2560	0.03					
Control 26	2880	0.03					

When the drawing speed exceeded 600 m./min. unevenness increased and number of fluff increased, when said speed exceeded 800 m./min. fluff and filaments breakage occurred often and satisfactory drawing cannot be carried out.

From results of Controls 9–26, it was understood that the drawing process using a hot pin was remarkably inferior to the process of the present invention in dyeing uneveness, stress uneveness and fluff.

EXAMPLES 16–18

Polyethylene terephthalate chips having various intrinsic viscosities (η) were melted, extruded through a spinneret having 48 orifices, would at a speed of 970 m./min. to obtain undrawn filaments of 349 denier. Using the apparatus shown in FIGS. 1 and 2, this undrawn filaments were drawn and heat-set under the following conditions.

Pre-tension—0.08 g./d.

Draw ratio—3.50

The number of wraps around the heated feed roller—8 times

Contact time with the heated feed roller—0.52 second

Surface temperature of the heated feed roller—83° C.

Diameter of the heated feed roller—100 mm.

Temperature of the portion in the slit heater where the filaments passed—220° C.

Properties of the obtained drawn, heat-set filaments were as shown in Table 6 below.

TABLE 6

	Chip [η]	Undrawn filament [η]	Tg(° C.)	Δn	Tension at which the neck occurs, g./d.	Tenacity, g./d.	Elongation, percent	Dyeing uneven-ness	Stress uneven-ness	Fluffs per 1,000,000 m.
Example 16	0.40	0.36	67	326×10^{-5}	0.37	3.13	12.3	0.0	12.0	0.8
Example 17	0.65	0.63	69	572×10^{-5}	0.42	5.02	27.8	0.0	11.6	0.4
Example 18	0.90	0.78	69	668×10^{-5}	0.45	6.86	25.9	0.5	14.9	0.6

From results of Controls 9–26, it was understood that the drawing process using a hot pin was remarkably inferior to the process of the present invention in dyeing uneveness, stress uneveness and fluff.

Controls 27–29

The undrawn filaments same as those of Examples 16–18 were drawn and heat-set by the conventional drawing process using a hot pin under the following conditions.

Pre-tension—0.08 g./d.

Draw ratio—3.50

Drawing speed—800 m./min.

Temperature of the drawing pin—83° C.

Diameter of the drawing pin—60 mm.

The number of wraps around the drawing pin—2 times

Heat-setting temperature (hot plate)—160° C.

Properties of the obtained drawn, heat-set filaments were as shown in Table 7.

TABLE 7

	Chip [η]	Tenacity, (g./d.)	Elongation, percent	Dyeing uneven-ness	Stress uneven-ness	Fluffs per 1,000,000 m.
Cont. 27	0.40	3.02	12.9	12.0	61.2	129.8
Cont. 28	0.65	4.96	28.4	12.0	68.5	0.9
Cont. 29	0.90	6.92	26.3	12.0	80.1	4.6

In a drawing process using a hot pin, when undrawn filaments having an (η) of 0.04 were drawn, many fluffs were brought about, filament breakage was often and satisfactory drawing could not be carried out. In accordance with the process of the present invention, sufficiently satisfactory results were obtained.

EXAMPLES 19–24

The undrawn filaments same as those of Examples 1–4 were drawn and heat-set under conditions same as in Examples 1–4 except making the temperature of the heated feed roller 85° C. and varying pre-tension by adjusting the speed of the delivery roller.

Properties of the obtained drawn, heat-set filaments were as shown in Table 8 below.

TABLE 8

	Ratio of roller speed [1]	Pretension, g.	Variation of tension, g./d.	Tenacity, g./d.	Elongation, percent	Dyeing uneven-ness	Stress uneven-ness	Fluffs per 1,000,000 m.
Ex. 19	1.0008	0.03	±0.01	5.10	28.4	1.5	13.2	29.6
Ex. 20	1.003	0.05	±0.01	4.99	27.3	0.5	9.0	1.2
Ex. 21	1.008	0.10	±0.01	5.06	27.9	0.0	7.5	0.4
Ex. 22	1.012	0.13	±0.01	5.01	28.5	0.5	8.4	0.9
Ex. 23	1.035	0.36	±0.02	5.08	27.6	2.5	16.3	4.5
Ex. 24		[2] 0.01	±0.08	5.04	28.0	4.0	28.7	2.1

[1] Ratio of roller speed = $\frac{\text{speed of the heated feed roller}}{\text{speed of the delivery roller}}$

[2] Pretension imparted by a thread brake (guide).

The preferable range of pre-tension of this drawn filaments was 0.04–0.33 (g./d.), and drawing under conditions outside this range resulted in increase of unevenness and fluff. In the process wherein pre-tension was imparted by a guide, unevenness was much and the process was not preferable.

EXAMPLE 25

Polyethylene terephthalate chips having an [η] of 0.90 were melted at 295° C., extruded through a spinneret having 250 orifices of diameters of 0.35 mm., wound at a speed of 500 m./min. to obtain undrawn filaments of 6141 denier. The undrawn filaments had an [η] of 0.79, a T_g of 69° C., a Δn of 203×10^{-5} and the tension at which the neck occurs of 0.40 g./d. This undrawn filaments were drawn by using the apparatus shown in FIGS. 1 and 2 under the following conditions.

Drawing speed—100 m./min.
Temperature of the heated feed roller—75° C.
Number of turns around the heated feed roller—6 times
Contact time of the filaments with the heated feed roller—5.35 second
Pre-tension—0.12 g./d.
Draw ratio—5.97
Temperature of the portion of the slit heater where the filaments pass—195° C.

The obtained drawn filaments had a tenacity of 8.59 g./d., an elongation of 11.2%, 2.5 fluffs per 1,000,000 m. and drawing went without any trouble. Whereas, in case no pressure roller was used, although there was no difference in tenacity had elongation, fluff increased to 5.6/1,000,000 m.

EXAMPLE 26

Chips of a polyethylene terephthalate-isophthalate copolymer containing 4.5 mol percent of isophthalic acid ([η]=0.64) were melted at 283° C., extruded through a spinneret having 24 Y-shaped orifices of diameters of 0.25 mm., wound at a speed of 1000 m./min to obtain undrawn filaments of 172 denier whose cross sectional configuration was triangular. This undrawn filaments had an [η] of 0.62, a T_g of 68° C. had the tension at which the neck occurs of 0.38 g./d.

This undrawn filaments were drawn by using the apparatus employed in Example 1 under the conditions of a pretension of 0.09 g./d. a drawing speed of 800 m./min., a draw ratio of 3.60, a temperature of the heated feed roller of 83° C., the number of turns of 8 times and a contact time of the filaments with the heated feed roller of 0.54 second.

The so obtained drawn filaments having triangular cross sectional configuration has a tenacity of 5.00 g./d., an elongation of 28.0%, dyeing uneveness of 0.5, stress unevenness of 6.5 g. and 0.8 fluff per 1,000,000 m.

Whereas, in said drawing, when the number of turns was 2 times, the drawn filaments had deteriorated properties of a tenacity of 5.08 g./d., an elongation of 26.0%, dyeing unevenness of 3.0, stress unevenness of 13.3 g. and 2.4 fluffs/1,000,000 m.

EXAMPLE 27

Undrawn filaments consisting predominantly of polyethylene terephthalate containing 11.8 mol percent of diethylene glycol of 175 denier having an [η] of 0.52, a second order transition point of 54° C., the tension at which neck occurs of 0.24 g./d. and a Δn of 448×10^{-5} was drawn by using the apparatus employed in Example 1 under conditions of a pre-tension of 0.07 g./d., a temperature of the heated feed roller of 70° C., the number of wraps of the filaments around said roller of 6 times, a draw ratio of 4.20, a drawing speed of 600 m./min. and a contact time of the filaments with the heated feed roller of 0.66 second while pressing the point where the filaments aparted from the roller by an elastic roller. The obtained drawn filaments had dyeing unevenness of 0.5, tress unevenness of 7.2 g., 1.1 fluffs/1,000,000 m., a tenacity of 4.83 g./d. and an elongation of 30.1%. In case, the number of turns was made 1 time, the obtained drawn filaments had dyeing unevenness of 4.0, stress unevenness of 15.6 g., 8.3 fluffs/1,000,000 m., a tenacity of 4.50 g./d. and an elongation of 28.5%.

EXAMPLE 28

Undrawn filaments of 171 denier consisting of polyethylene terephthalate containing 0.2 mol percent of pentaerythritol having an intrinsic viscosity [η] of 0.63, a second order transition point of 67° C., the tension at which the neck occurs of 0.40 g./d. and a Δn of 523×10^{-5} were drawn by the apparatus employed in Example 1, under conditions of a pre-tension of 0.09 g./d., a drawing speed of 500 m./min., a draw ratio of 3.40, a temperature of the heated feed roller of 85° C., the number of wraps of the filaments around the heated feed roller of 6 times, a contact time of the filaments with the heated feed roller of 0.42 second and the angle α and the contact pressure of an elastic roller same as those of Example 26.

The obtained drawn filaments had a tenacity of 3.65 g./d., an elongation of 28.8%, dyeing unevenness of 0.5, stress unevenness of 7.6 g. and 1.2 fluffs/1,000,000 m.

Whereas, in case the drawing speed was made 2000 m./min., a contact time of the filaments with the heated feed roller became 0.10 second and the obtained drawn filaments had a tenacity of 3.48 g./d., an elongation of 27.5%, dyeing unevenness of 5.0, stress unevenness of 17.3 g. and 8.2 fluffs/1,000,000 m.

EXAMPLES 29–30

Undrawn filaments were drawn under conditions same as in Examples 5–10 and when comparison was made in case a slit heater having effective length of 400 mm. for

heat-setting was used and in case a hot plate was used, the results as shown in Table 9 below were obtained. Temperature of the portion of the slit heater where the filaments passed was 240° C. and surface temperature of the hot plate was 160° C.

TABLE 9

	Heat-treating apparatus	Tenacity, g./d.	Elongation, Percent	Dyeing uneven-ness	Stress uneven-ness	Fluffs per 1,000,000 m.
Ex. 29	Slit heater	5.02	28.8	0.0	8.6	0.4
Ex. 30	Hot plate	5.09	28.2	0.5	12.4	1.8

What is claimed is:

1. A process for drawing a bundle of undrawn thermoplastic saturated linear polyester filament having a filament denier below 150 and containing at least 80 mol percent of ethylene terephthaltate units, which comprises passing said undrawn filaments in a plurality of wraps around a positively rotated heated feed roller which cooperates with a freely rotatable pressure roller and from the feed roller to a draw roller which is rotating at a peripheral speed which is higher than the peripheral speed of the feed roller to thereby draw the filaments to 2.0–6.0 times its original length, the pressure roller having an elastic outer surface and being arranged so that at least the last wrap of the filament around the feed roller is pressed into contact with the outer surface of the feed roller, the point of contact being such that an angle (α) formed by a radius conencting the point where the filaments would depart from the feed roller if the pressure roller were not used with the center of the feed roller and a radius connecting the said point of contact with the center of the feed roller does not exceed 20°, the surface temperature (T° C.) of the heated feed roller being within the range of the second order transition point of the undrawn filaments (T_g° C.) to a temperature 55° C. higher than the said second order translation point with the contact time of the undrawn filaments with the heated feed roller (t sec.) satisfying the equation:

$$-0.120(T-T_g)+28.420 \geqq t \geqq -0,003(T-T_g)+0.189$$

2. The process of claim **1** wherein the contact time satisfies the equation:

$$-0.120(T-T_g)+7.72 \geqq t \geqq -0.003(T-T_g+0.189$$

3. A process described in claim **1**, wherein a pre-tension is imparted to the undrawn filaments before they are passed around the feed roller, such a pre-tension being within the range of 10 to 90% of the tension at which a neck occurs as shown in a stress-strain curve of the undrawn filaments measured at a temperature of 20° C. and a relative humidity of 65%.

4. A process described in claim **1**, wherein said polyester filaments consist of polyethylene terephthalate.

5. A process described in claim **1** wherein said surface temperature of said heated feed roller is within the range of (T_g+5)° C. (T_g+25)° C.

6. A process described in claim **1** wherein said angle (α) is within the range of 0° to 3°.

7. An apparatus for drawing a bundle of undrawn thermoplastic saturated linear polyester filaments having a filament denier below 150 and containing at least 80 mol percent of ethylene terephthalate units, which comprises a positively rotatable feed roller which is adapted to heat undrawn filaments wound around the outer surface thereof and advance the heated fibers at a predetermined speed, means for imparting a pre-tension to the undrawn filaments before they are wound around the feed roller, a positively rotatable draw roller adapted to rotate at a peripheral speed which is higher than the peripheral speed of the feed roller for withdrawing the heated filaments from the feed roller and a freely rotatable pressure roller having an elastic outer surface and contacting the outer surface of the feed roller so that at least the last wrap of undrawn filaments is pressed into contact with the outer surface of the feed roller, the point of contact being such that an angle (α) formed by a radius connecting the center of the feed roller and the said point of contact and a radius connecting the center of the roller with the point where filaments would depart from the feed roller if the pressure roller were not used does not exceed 20°.

8. The apparatus of claim **7**, further including means for heat treating the filaments during their passage from the feed roller to the draw roller.

9. The apparatus of claim **8**, wherein the means for heat treating the filaments is a slit heater.

10. The apparatus of claim **7**, wherein the pretension means comprises a nip roller and a delivery roller which in use of the apparatus is adapted to rotate at a peripheral speed in the range of 1/1.0001 to 1/1.030 of the peripheral speed of the feed roller.

References Cited

UNITED STATES PATENTS

3,092,891	6/1963	Baratti	264—290
3,256,134	6/1966	Rice	161—172
3,302,385	2/1967	Ruddell et al.	
3,358,344	12/1967	Daniel	264—168 X
3,374,302	3/1968	Stanley	264—168 X
3,376,622	4/1968	Stanley	264—168
3,379,809	4&1968	Woods	264—168
3,381,461	5/1968	Chubb	264—168 X
3,404,525	10/1968	Tompkins	57—140

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