

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) FALSE-TWIST - CRIMPED YARN

(71) We, TEIJIN LIMITED, a Japanese Body Corporate of No. 1, Umeda, Kita-ku, Osaka, Japan, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to false twist-crimped polyester yarns, the term "polyester" being used herein to denote a polyester containing at least 80 mole % of ethylene terephthalate units.

It is known to produce a yarn of crimped polyester filaments by false twisting a traveling polyester yarn and heat-setting the false-twisted yarn before it passes through the false-twisting device. However, the known false twist-crimped polyester yarns do not have a satisfactory combination of crimp properties and dyeability. In the known processes it is necessary to use high temperatures (usually 210—230°C) to obtain adequate heat-setting to provide satisfactory crimp properties, and the use of such temperatures results in deterioration of other properties of the yarn. In particular the yarns so-produced have reduced dyeability (dye exhaustion often less than 80% with disperse dyes) and even small variations in the heat-setting temperature result in yarns which have substantially non-uniform dyeability. It is often necessary to blend yarns from different false twist spindles in order to obtain a sufficiently uniform product.

It is also known to modify false twist-crimped polyester yarns by subjecting them to a second heat-treatment. However, the disadvantages pointed out above remain in the modified yarns.

The present invention provides novel false twist-crimped yarns having a very satisfactory combination of good crimp properties and good and level dyeability, and a process for producing such yarns which is simpler and cheaper to operate than the known processes.

In its first aspect the invention provides a false twist-crimped polyester yarn having a density (d) of $1.3800 \leq d \leq 1.3950$ (g/cm³)

and a total percentage crimp (TC) of $TC \geq 30$ (%).

In its second aspect the invention provides a modified false twist-crimped polyester yarn having a density (d) of $1.3800 \leq d \leq 1.3950$ (g/cm³) a total percentage crimp (TC) of $TC \leq 20$ (%), and a torque (Tq) of $Tq \leq 26$ (T/25 cm).

Conventional false twist-crimped polyester yarn has a density (d) of $1.398 \leq d \leq 1.410$ — Conventional modified false twist-crimped polyester yarn also has such a density and in addition has a torque of more than 30 when its TC is more than 20%.

In its third aspect the invention provides a process for producing a false twist-crimped polyester yarn which comprises false twisting a polyester multifilament yarn having a birefringence (Δn) of $0.030 \leq \Delta n \leq 0.145$, preferably $0.06 \leq \Delta n \leq 0.135$, while heat-setting said multifilament yarn in the twisted state at 160° to 210°C., preferably 170° to 200°C., at a draft (d_r) expressed by the relation

$$-250. \Delta n + 38 \geq d_r \geq -150. \Delta n + 17$$

In its fourth aspect, the invention provides a process for producing a modified false twist-crimped polyester yarn which comprises subjecting the false twist-crimped yarn obtained by this process to a second heat-setting at a temperature in excess of that at which said yarn has been initially heat set.

In the known processes, the birefringence (Δn) of the starting polyester multifilament yarn has been at least 0.16 and it has not previously been suggested that the draft should be varied according to the birefringence of the starting yarn. Furthermore it has been necessary to heat-set the yarn, as it is being false-twisted, at higher temperatures of 210° to 230°C. We have found, in accordance with the invention, that by employing a starting yarn of lower birefringence between 0.030 and 0.145, a product of similar crimp properties can be obtained at lower heat-setting temperatures of 160° to 210°C., and furthermore that

by controlling the tension on the yarn during heat-setting, by maintaining the draft (d_r) within the range set out above, the product has good and level dyeability.

- 5 The birefringence (Δn), total percentage crimp (TC), dye exhaustion (L-value), Torque and Density values given herein are measured as follows:

(A) Birefringence (Δn)

- 10 Sodium D rays (wavelength 589 millimicrons) are used as a light source, and the filaments are disposed in a diagonal position. The birefringence (Δn) of the specimen is computed from the following equation:

$$15 \quad \Delta n = \frac{n\lambda + r}{\alpha}$$

where n is the interference fringe due to the degree of orientation of the polymer molecular chain; r is the retardation obtained by measuring the orientation not developing into the interference fringe by means of a Berek's compensator; α is the diameter of the filament; and λ is the wavelength of the sodium D rays.

(B) Total Percentage Crimp (TC)

- 25 The yarn is placed under two loads, a lighter load of 2 mg/de (milligrams per denier) and a heavier load of 0.2 g/de (grame per denier). After a lapse of 1 minute, the length (l_0) is measured. Immediately the heavier load is removed, and the yarn under the lighter load is placed in boiling water. It is taken out of the water 20 minutes later. The lighter load is removed, and the yarn is dried under ambient conditions for 24 hours. Both loads are again placed on the dried yarn, and its length (l_2) is measured after a lapse of 1 minute. Immediately, the heavier load is removed, and after a lapse of 1 minute, its length (l_3) is measured. The total percentage crimp (TC) is expressed by the equation:

$$TC = \frac{l_2 - l_3}{l_0} \times 100 (\%)$$

(C) Dye exhaustion (L value)

- The yarn processed is knitted on a circular knitting machine. The knitted article is dyed for 30 minutes in boiling water using a dye bath containing 3—4% of Eastmann Polyester Blue BLF and 0.5 g/liter of "Monogen" (Registered Trade Mark) at a goods-to-liquor ratio by weight of 1:100. The lightness (L-value) of the dyeing is measured by a CM—20 type color differential meter, Nippon Color Machine Company. This L-value is employed as the dye exhaustion. Larger L-values mean lighter colors, and smaller L-values mean darker colors.

(D) Torque

A length of about 1m. of the yarn is held in a generally horizontal position and a load of 1 mg/de is placed at the centre of the yarn. The two ends of the yarn are then brought together, which causes the two halves of the yarn to twist together. The torque is the number of twists in a length (y) of the doubled twisted yarn which contains two 25 cm lengths of yarn (i.e. one 25 cm. length from each half of the yarn). Because the doubled yarn is shortened by the twisting together of the two halves, the length (y) is less than 25 cm. The number of twists can be determined visually or by turning the load until all the twist is removed. Twenty such measurements are made and the average is taken.

(E) Density:

The yarn is put into a density gradient tube of n-heptane-carbon tetrachloride (25°) using a float (made by Shibayama Scientific Instruments Works, Ltd.). The density is measured after a lapse of 48 hours.

To facilitate understanding of the invention, reference may be made to the accompanying drawings in which:

Figure 1 shows the relation between the heat-setting temperature (temperature of the filament) and the time needed to cause secondary crystallization;

Figure 2 shows one example of the relation between the heat-setting temperature and the dye exhaustion (L-value) and the total percentage crimp;

Figure 3 shows the relation between the birefringence of the starting yarn and the draft (d_r);

Figure 4 shows diagrammatically one example of apparatus suitable for use in the present invention;

Figure 5 shows the relation between the birefringence of an undrawn polyester filament and the draw ratio; and

Figure 6 shows diagrammatically one example of a drawing apparatus suitable for producing a polyester filament having a birefringence $0.030 \leq \Delta n \leq 0.145$.

Referring to Figure 1, the abscissa measures the temperature of the filament on the heater, and the ordinate measures the time needed to cause secondary crystallization to take place. The curve a is for a conventional polyester filament, and the curve b is for a polyester filament suitable for use as starting yarn in the present invention. The denier size (denier per filament or de/fil), birefringence and draft of the filaments used are:—

	a	b	
Denier size (de/fil)	75/24	75/24	115
Birefringence (Δn)	0.168	0.085	
Draft (%)	— 4	8	

By the term "time needed to cause secondary crystallization", we mean the time which elapses before a substantially straight line relation is established between the logarithm of the time elapsed and the density of the specimen. In order to obtain good crimps, the time should be between t_1 and t_2 and the secondary crystallization should not take place before the crimps have set. It will be seen that for the conventional yarn, the temperature must be from T_3 to T_4 (usually 210–230°C) for these conditions to be fulfilled, whereas for the starting yarn used in this invention the temperature is lower, namely from T_1 to T_2 ; this difference is presumably due to different crystalline structures.

Referring now to the lower part of Figure 2, the dye exhaustion of the yarn of the invention is shown by curve b_1 and the dye exhaustion of conventional false twist-crimped polyester yarn by curve a_1 . It will be seen that the novel yarn has dyeability that not only is better than conventional yarn but also varies much less with variations in the heat-setting temperature in the ranges employed to give good crimps.

Referring now to the upper part of Figure 2, the curves a_2 and b_2 represent the total percentage crimps of the crimped yarns corresponding to a_1 and b_1 . The total percentage crimp of the crimped polyester yarn of the invention becomes maximum at a temperature in the range of 160° to 210°C., especially 170° to 200°C, within which excellent level dyeing properties and dyeability can be obtained. In contrast, with the conventional false twist-crimped polyester yarns, the total crimp become maximum at 210° to 230°C., and above, at which heat-setting temperatures the crimped polyester yarns suffer from large fluctuations in dyeing difference (ΔD) with the temperature difference (ΔT) and also reduced dye exhaustion.

Referring now to Figure 3, the shaded area (hijk) shows the drafts that are employed in accordance with the invention and the doubly shaded area (lmno) shows the drafts employed when the starting yarn has a birefringence within the preferred range of 0.06 to 0.135. This corresponds to a yarn tension during twisting of 0.05 to 0.15 g/de. In the area generally designated A_2 , the yarn tension is too low and the product contains untwisted filaments and melt-adhered filaments. In the area A_3 the tension is too high and the product has poor crimp characteristics. In the area A_1 , the treatment has little or no effect on the yarn and in the area A_4 the product is not substantially better than known yarns.

Referring now to Figure 4, polyester filament yarn 2 wound on pirn 1 passes snail guide 3 and is delivered by a pair of feed rollers 4 and 4'. It then passes heater 5 and false twist spindle 6, and is then taken up by a pair of delivery rollers 7 and 7'. It is then

wound up on bobbin 9 which is rotated frictionally by roller 8. Generally the draft (d_r) is determined by the following equation.

$$\text{draft } (d_r) = \frac{V_2 - V_1}{V_1} \times 100 (\%)$$

wherein V_1 is the peripheral speed of the feed roller 4, 4' and V_2 is the peripheral speed of delivery roller 7, 7'.

The type of the false twist crimping is not critical, but the spindle method is especially preferred. If desired, a secondary heater may be provided between the spindle 6 and the delivery rollers 7 and 7', or between rollers 7, 7' and roller 8, in order to heat-treat the crimped yarn and reduce the torque of the said yarn.

The starting yarn for the process of the invention can be obtained by drawing an ordinary undrawn polyester yarn at a low draw ratio in dry heat using heated feed roller, pin or plate or in wet heat (e.g. a warm water bath). The draw ratio (Dr) should be adjusted to produce the desired birefringence (Δn), and we have found that the following relationships exist (Δn_u being the birefringence of the undrawn yarn).

(i) when $0.002 \leq \Delta n_u \leq 0.010$

$$-100. \Delta n + 2.50 \leq Dr \leq -120. \Delta n + 4.00 \quad \dots (II)$$

(ii) when $0.010 \leq \Delta n_u \leq 0.020$

$$-25. \Delta n + 1.75 \leq Dr \leq -90. \Delta n + 3.7 \quad \dots (III)$$

In Figure 5, the range which satisfies the above relations is shown by the shaded area. If the draw ratios which satisfy the above relations (II) and (III) are used according to the birefringence of the undrawn yarn, the drawn polyester filaments can have a birefringence of 0.030 to 0.145.

In Figure 6, the numeral 10 denotes a cheese, 11 an undrawn polyester yarn, 12 a roller for exerting a preliminary tension, 13 a hot feed roller, 14 a draw roller, 15 a guide and 16 a drawn yarn. In the drawing of an undrawn polyester yarn using this apparatus, it is preferable to impart a preliminary tension to the yarn to an extent such that the undrawn yarn will not substantially be drawn between the roller 12 and the hot roller 13. This can desirably be done by controlling the peripheral speed ratio between the roller 12 and the hot roller 13. The proper ratio of peripheral speed between the roller 12 and the hot roller 13 is 1:1.001–1.030. A heat-treating device such as a slit heater or hot plate may be provided between the hot roller and

the draw roller in order to heat set the drawn yarn.

When drawing in wet heat is employed, filaments which are molecularly oriented uniformly to the desired degree and free from necking can be obtained by maintaining the drawing tension at 0.01 to 1.00 g/de in a water bath at 80 to 100°C. The drawing tension depends upon such factors as the type of undrawn yarn, the temperature of the draw bath, the draw ratio and the draw speed. In the case of a 155 denier/24 filaments undrawn polyester yarn having a birefringence of 0.0105 and an intrinsic viscosity of 0.59, the drawing tension will become 0.01—1.00 g/de when the yarn is drawn at a draw ratio of 1.40 to 2.80 at a draw bath temperature of 90°C. and at a feed rate of 300 meters per minute.

Other methods of drawing are also available. For instance, an undrawn filament yarn extruded from a spinning nozzle can be drawn between two pairs of rollers without prior wind-up, or an undrawn filament extruded from a spinning nozzle can be first wound up on a bobbin rotating at peripheral speed of 3,000 meters per minute, and molecular orientation is induced in the meantime to form filaments having the desired birefringence.

The undrawn polyester yarn used in the present invention is substantially non-oriented polyester filament consisting of a polyester containing at least 80 mole % of ethylene terephthalate units. The preferred polyester is polyethylene terephthalate, but there may also be used copolyesters containing less than 20 mole % of other copolymerisable components. Examples of other acid components to be copolymerized with ethylene terephthalate include dibasic acids such as phthalic acid, isophthalic acid, adipic acid, oxalic acid, sebacic acid, suberic acid, glutaric acid, pimelic acid, fumaric acid, or succinic acid. Examples of other alcohol components that can be copolymerized with ethylene terephthalate are dihydric alcohols such as polymethylene glycols having 2 to 10 carbon atoms (trimethylene glycol and butylene glycol, for example) and cyclohexane dimethanol.

The polyester may contain a minor amount of a modifier such as 5-oxymethyl isophthalate, 5-oxymethyl hexahydrosophthalate, benzene-1,3,5-tricarboxylic acids, para-carbomethoxyphenyl diethyl phosphonate, 3,5-dicarboxy phenyl diethyl phosphonate, pentaerythritol, glycol, phosphoric acid, triphenyl phosphate, tri-1-carbomethoxyphenyl phosphate, triphenyl arsenite, tricapryl boric acid, sorbitan, trimesic acid, or diethylene glycol. Furthermore, the polyester may contain a small amount of other polymer such as polyamide, polycarbonate, or polyolefins.

The undrawn polyester yarns used in the present invention may be those obtained by melt-spinning the aforementioned-polyesters. Especially preferred are those having a denier

size of not more than 150 denier per monofilament, a birefringence of 0.002 to 0.020, and an intrinsic viscosity of 0.3—1.2, as computed from the value measured in o-chlorophenol at 35°C. The drawing of an undrawn yarn composed of a polyester having an intrinsic viscosity of less than 0.5 presents difficulties in operation such as the occurrence of fuzzes in an ordinary hot pin drawing procedure. In such a case, the undrawn yarn of a polyester of low degree of polymerization can be satisfactorily drawn by using the hot roller drawing procedure.

The undrawn yarn may have not only a circular section, but also a non-circular section such as triangular, quadrilateral, pentagonal, flat, or cruciform section and a hollow section such as an annular or non-circular hollow section.

A particular advantage of the process of the invention is that, because lower yarn temperatures are needed in the heat-setting process, higher operating speeds are possible.

The invention will further be described by the following Examples.

Example 1.

Polyethylene terephthalate chips having an intrinsic viscosity of 0.65 were melted at 288°C., and extruded through a spinneret having 24 orifices each having a diameter of 0.25 mm, followed by winding up as undrawn filaments. The intrinsic viscosity of the undrawn filaments was 0.63, and they had a birefringence of 1050×10^{-4} . The drawing conditions of the undrawn filaments, the properties of the drawn filaments, and the conditions under which the drawn filaments were false twist-crimped by using a false twisting crimping machine of the type shown in Figure 4 are shown in Table 1, in which the number of false twists (T/M) is the amount of twist in turns per metre inserted by the false twisting spindle.

Ten spindles were used for the crimping of the drawn filaments. The temperatures were varied from spindle to spindle by a maximum of $\pm 4^\circ\text{C}$. based on the standard spindle. Thus, ten false twist-crimped yarns were obtained. The total percentage crimps (TC) of these crimped yarns and their dyeing characteristics are shown in Table 2. Table 2 also shows "Density of standard spindle," which means the density of the yarn produced by the standard spindle operating at the processing temperature shown. It is seen from Table 2 that according to the present invention, even if the temperature non-uniformity among the spindles exists, crimp non-uniformity of the yarns does not occur, and the dye exhaustion difference ($\Delta D = \text{maximum dye exhaustion} - \text{minimum dye exhaustion}$) is negligibly small at temperatures at which the total percentage crimps of the yarns are large.

TABLE 1

Sample		A	B	C	D
Dyeing conditions	heating means	warm water	hot roller	hot roller	warm water
	temperature (°C.)	95	85	85	95
	draw ratio (x)	1.80	2.73	2.73	1.80
	draw speed (m/min)	600	1000	1000	600
Physical properties of the drawn yarn	denier size (de/fil.)	944/24	78.8/24	76.4/24	89.9/24
	birefringence (Δn)	0.045	0.138	0.138	0.045
	tenacity at break (g/de)	3.2	3.8	3.8	3.2
	elongation at break (%)	135	45	45	135
	density (g/cm ³)	1.350	1.365	1.365	1.350
False twist crimping conditions	number of false twists (T/M)	3380	3380	3380	3380
	draft (%)	21	1	-2	14
	processing speed (m/min)	100	100	100	100
	twist tension at 190°C. (gr/de)	0.108	0.110	0.089	0.072

TABLE 2

Processing temperature (°C.)	Sample	Total percentage crimp		Dyeing properties		Density of standard spindle (g/cm ³)
		Standard spindle (TCs)	Crimp difference (ΔTC)	Standard spindle (Ds)	Dyeing difference (ΔD)	
170	A	38.3	≤ 5.0	35.2	≤ 0.4	1.3875
	B	32.6	≤ 5.0	37.8	≤ 0.4	1.3874
	C	33.4	≤ 5.0	37.5	≤ 0.4	1.3876
	D	38.5	≤ 5.0	35.7	≤ 0.4	1.3875
180	A	43.1	≤ 4.0	35.3	≤ 0.2	1.3899
	B	38.4	≤ 4.0	37.9	≤ 0.2	1.3897
	C	39.0	≤ 4.0	37.5	≤ 0.2	1.3896
	D	43.6	≤ 4.0	35.8	≤ 0.2	1.3898
190	A	45.8	≤ 2.0	35.3	≤ 0.2	1.3920
	B	40.7	≤ 4.0	37.9	≤ 0.2	1.3919
	C	41.5	≤ 4.0	37.6	≤ 0.2	1.3921
	D	45.9	≤ 2.0	35.8	≤ 0.2	1.3921
200	A	45.1	≤ 2.0	35.2	≤ 0.8	1.3945
	B	44.8	≤ 2.0	37.6	≤ 0.8	1.3943
	C	45.0	≤ 2.0	37.5	≤ 0.8	1.3944
	D	45.7	≤ 2.0	35.6	≤ 0.8	1.3942
210	A	42.6	≤ 3.0	34.6	≤ 1.5	1.3965
	B	44.3	≤ 2.0	37.0	≤ 1.5	1.3963
	C	44.6	≤ 2.0	36.9	≤ 1.5	1.3964
	D	43.0	≤ 3.0	34.9	≤ 1.5	1.3965

Example 2.

The conditions for the drawing of undrawn filaments obtained in Example 1, the properties of the resulting drawn filaments, and the conditions for false twist crimping of the drawn filaments using a false twisting crimping apparatus of the type shown in Figure 4 are given in Table 3.

Ten spindles were used for crimping of drawn yarns, and the temperatures were varied from spindle to spindle by a maximum

of $\pm 4^{\circ}\text{C}$. based on the standard spindle. Ten false twist-crimped yarns were obtained. The total percentage crimp and dyeing characteristics are given in Table 4. It is seen from the results shown in the Table 4 that according to the present invention, even if the temperature non-uniformity exists among the spindles, crimp non-uniformity of the yarns does not occur, and the dye exhaustion difference is still small at temperatures at which the total percentage crimps of the yarns are large.

TABLE 3

	Sample	E	F	G	H
	heating means	warm water	hot roller	hot roller	warm water
Drawing conditions	temperature ($^{\circ}\text{C}$.)	95	85	85	95
	draw ratio (x)	2.10	2.64	2.54	2.10
	draw speed (m/min)	600	1000	1000	600
	denier size (de/fil.)	90.5/24	82.7/24	79.6/24	85.8/24
Physical properties of the drawn yarn	birefringence (Δn)	0.078	0.115	0.115	0.078
	tenacity at break (g/de)	3.4	3.7	3.7	3.4
	elongation at break (%)	92	60	60	92
	density (g/cm ³)	1.354	1.362	1.362	1.354
	number of false twists (T/M)	3380	3380	3380	3380
False twist	draft (%)	16	6	2	10
Crimping conditions	processing speed (m/min)	100	100	100	100
	twist tension at 190°C . (gr/de)	0.110	0.102	0.087	0.093

TABLE 4

Processing temperature (°C.)	Sample	Total percentage crimp		Dyeing properties		Density of standard spindle (g/cm ³)
		Standard spindle (TCs)	Crimp difference (Δ TC)	Standard spindle (Ds)	Dyeing difference (Δ D)	
170	E	37.4	≤ 5.0	36.5	≤ 0.4	1.3873
	F	35.6	≤ 5.0	36.9	≤ 0.4	1.3875
	G	36.8	≤ 5.0	36.8	≤ 0.4	1.3875
	H	38.1	≤ 5.0	35.7	≤ 0.4	1.3874
180	E	44.8	≤ 4.0	36.8	≤ 0.2	1.3900
	F	43.7	≤ 4.0	37.2	≤ 0.2	1.3898
	G	44.2	≤ 4.0	36.9	≤ 0.2	1.3897
	H	44.6	≤ 4.0	36.1	≤ 0.2	1.3899
190	E	45.1	≤ 2.0	36.8	≤ 0.2	1.3917
	F	44.5	≤ 4.0	37.1	≤ 0.2	1.3820
	G	45.4	≤ 4.0	36.8	≤ 0.2	1.3822
	H	46.0	≤ 2.0	36.0	≤ 0.2	1.3819
200	E	45.2	≤ 2.0	36.7	≤ 0.8	1.3942
	F	44.8	≤ 2.0	37.1	≤ 0.8	1.3945
	G	45.2	≤ 2.0	36.7	≤ 0.8	1.3944
	H	46.3	≤ 2.0	35.8	≤ 0.8	1.3943
210	E	42.8	≤ 3.0	36.1	≤ 1.5	1.3964
	F	44.4	≤ 2.0	36.2	≤ 1.5	1.3962
	G	44.7	≤ 2.0	35.9	≤ 1.5	1.3968
	H	43.5	≤ 3.0	34.0	≤ 1.5	1.3965

Comparative Example 1.

5 The conditions for drawing the undrawn yarn obtained in Example 1, the properties of the drawn yarns, and the conditions for false twist crimping of the drawn yarns using a false twist-crimping apparatus shown in Figure 4 are given in Table 5.

10 Ten spindles were used for the crimping of the drawn yarns. The temperatures were varied from spindle to spindle by maximum of $\pm 4^\circ\text{C}$. based on the standard spindle. Thus, ten false twist-crimped yarns were obtained. The total percentage crimps and dyeing properties of these crimped yarns are shown in Table 6. It is seen from Table 6 that in Samples M and O, non-untwisted yarns and

20 melt-adhered yarns occurred and it was impossible to obtain crimped yarns of practical values, and that in Samples I and K in which the twisting tension was large, the crimp properties of the yarns are poor; in addition there is a large difference (Δ D) in dye exhaustion at processing temperatures at which the total percentage crimp is relatively large, 25 which in turn produces the tendency of the dyeing non-uniformity among the spindles. By a non-untwisted yarn we mean a yarn in which the twist inserted in the filaments before the yarn passes through the false twister is not 30 completely removed after the yarn has passed through the false twister.

TABLE 5

Sample		I	K	M	O
heating means		warm water	hot roller	hot roller	warm water
Drawing conditions	temperature (°C.)	95	85	85	95
	draw ratio (x)	1.80	2.73	2.73	1.80
	draw speed (m/min)	600	1000	1000	600
	denier size (de/fil.)	105/24	85.8/24	73.6/24	81.9/24
Physical properties of the drawn yarn	birefringence (Δn)	0.045	0.138	0.138	0.1045
	tenacity at break (g/de)	3.2	3.8	3.8	3.2
	elongation at break (%)	135	45	45	135
	density (g/cm ³)	1.350	1.365	1.365	1.350
number of false twists (T/M)		3380	3380	3380	3380
False twist crimping conditions	draft (%)	35	10	-6	5
	processing speed (m/min)	100	100	100	100
	twist tension at 190°C. (gr/de)	0.25	0.35	0.04	0.03

TABLE 6

Processing temperature (°C.)	Sample	Total percentage crimp		Dyeing properties		Density of standard spindle (g/cm ³)
		Standard spindle (TCs)	Crimp difference (ΔTC)	Standard spindle (Ds)	Dyeing difference (ΔD)	
170	I	23.5	≤ 5.0	43.6	≤ 0.5	1.3872
	K	14.3	≤ 5.0	45.7	≤ 0.5	1.3874
	M	(occurrence of non-untwisted yarns)				
	O	(occurrence of non-untwisted yarns and melt-adhered yarns)				
190	I	28.7	≤ 3.0	45.1	≤ 0.3	1.3920
	K	20.2	≤ 3.0	46.8	≤ 0.3	1.3918
	M	(occurrence of non-untwisted yarns)				
	O	(occurrence of non-untwisted yarns and melt-adhered yarns)				
210	I	33.4	≤ 2.0	44.2	≤ 1.5	1.3963
	K	28.5	≤ 2.0	45.6	≤ 1.5	1.3964
	M	(occurrence of non-untwisted yarns and melt-adhered yarns)				
	O	(occurrence of non-untwisted yarns and melt-adhered yarns)				
220	I	31.76	≤ 2.0	41.6	≤ 2.5	1.3993
	K	34.6	≤ 2.0	42.1	≤ 2.5	1.3990
	M	(occurrence of non-untwisted yarns and melt-adhered yarns)				
	O	(occurrence of non-untwisted yarns and melt-adhered yarns)				
230	I	27.5	≤ 5.0	37.8	≤ 5.0	1.4009
	K	29.6	≤ 5.0	38.2	≤ 5.0	1.4007
	M	(occurrence of non-untwisted yarns and melt-adhered yarns)				
	O	(occurrence of non-untwisted yarns and melt-adhered yarns)				

Comparative Example 2.

The conditions for drawing the undrawn yarns obtained in Example 1, the properties of the resulting drawn yarns, and the conditions for twist crimping of the drawn yarns using a false twist crimping machine of the type shown in Figure 4 are shown in Table 7.

Ten spindles were used for crimping the drawn yarns, and the processing temperatures were varied from spindle to spindle by maxi-

mum of $\pm 4^{\circ}\text{C}$. based on the standard spindle. Thus, ten false twist-crimped yarns were obtained. The total percentage crimps and dyeing properties are given in Table 8. It is seen from the table that in Samples J and P in which the birefringence of the drawn yarn was low, non-untwisted yarns and melt-adhered yarns occur, and dyeing non-uniformity occurred, making it impossible to obtain crimped yarns of practical values.

TABLE 7

Sample		J	L	N	P
heating means		warm water	hot roller	hot roller	warm water
Drawing conditions	temperature ($^{\circ}\text{C}$.)	95	82	82	95
	draw ratio (x)	1.40	3.04	3.04	1.40
	draw speed (m/min)	200	1000	1000	200
	denier size (de/fil.)	101./24	81.1/24	74.0/24	89.7/24
Physical properties of the drawn yarn	birefringence (Δn)	0.021	0.168	0.168	0.021
	tenacity at break (g/de)	3.0	5.1	5.1	3.0
	elongation at break (%)	160	28	28	160
	density (g/cm ³)	1.348	1.380	1.380	1.348
number of false twists (T/M)		3380	3380	3380	3380
False twist crimping conditions	draft (%)	30	4	-4	15
	processing speed (m/min)	100	100	100	100
	twist tension at 190°C . (gr/de)	0.084	0.385	0.100	0.036

TABLE 8

Processing temperature (°C.)	Sample	Total percentage crimp		Dyeing properties		Density of standard spindle (g/cm ³)
		Standard spindle (TCs)	Crimp difference (Δ TC)	Standard spindle (Ds)	Dyeing difference (Δ D)	
170	J	(occurrence of non-untwisted yarns and melt-adhered yarns)				
	L	14.7	≤ 8	45.2	≤ 0.5	1.3873
	N	21.3	≤ 8	43.6	≤ 0.5	1.3872
	P	(occurrence of non-untwisted yarns and melt-adhered yarns)				
190	J	(occurrence of non-untwisted yarns and melt-adhered yarns)				
	L	21.4	≤ 8	46.4	≤ 0.3	1.3919
	N	28.6	≤ 5	44.0	≤ 0.3	1.3921
	P	(occurrence of non-untwisted yarns and melt-adhered yarns)				
210	J	(occurrence of non-untwisted yarns and melt-adhered yarns)				
	L	32.6	≤ 3	44.3	≤ 1.5	1.3963
	N	36.4	≤ 5	42.2	≤ 1.5	1.3964
	P	(occurrence of non-untwisted yarns and melt-adhered yarns)				
220	J	(occurrence of non-untwisted yarns and melt-adhered yarns)				
	L	34.1	≤ 3	41.5	≤ 2.5	1.3994
	N	42.7	≤ 3	39.5	≤ 2.5	1.3991
	P	(occurrence of non-untwisted yarns and melt-adhered yarns)				
230	J	(occurrence of non-untwisted yarns and melt-adhered yarns)				
	L	31.8	≤ 5	37.5	≤ 5.0	1.4006
	N	44.9	≤ 5	35.9	≤ 5.0	1.4005
	P	(occurrence of non-untwisted yarns and melt-adhered yarns)				

5 In Samples L and N in which the birefringence of the drawn yarn is large as in the conventional drawn yarns that are commercially available, the yarns have good total percentage crimps at the processing temperatures above 210°C. But in this temperature range, the dye exhaustion difference becomes maximum, and the dyeing non-uniformity tends to occur among the spindles.

Example 3.

15 Polyethylene terephthalate chips having an intrinsic viscosity of 0.65 were melted at 288°C., extruded through a spinneret having 30 orifices each having a diameter of 0.25 mm, and wound-up as undrawn yarns. The undrawn yarns had an intrinsic viscosity of 0.62 and a birefringence of 560×10^{-5} . The conditions for drawing these undrawn yarns,

the properties of the resulting drawn yarns, and the conditions for false twist crimping of the drawn yarns using a false twist crimping machine of the type shown in Figure 4 in which second heat-treating devices are arranged between 7, 7' and 8 are shown in Table 9.

20 Ten spindles were used for crimping of the drawn yarns, and the processing temperatures were varied from spindle to spindle by a maximum of $\pm 4^\circ\text{C}$. based on the standard spindle. The total percentage crimps, dyeing properties, and torques of the crimped yarns are shown in Table 10. It is seen from this table that according to the present invention, even if the temperature non-uniformity occurs among the spindles, the crimped yarns have little crimp non-uniformity, and small dyeing differences and torque at the temperatures at which the total percentage crimps are large.

TABLE 9

Sample		Q	R	S	T
Drawing conditions	heating means	warm water	hot roller	hot roller	hot roller
	temperature (°C.)	98	87	85	85
	draw ratio (x)	2.40	2.60	2.85	3.04
	draw speed (m/min)	600	800	800	800
Physical properties of the drawn yarn	denier size (de/fil)	168.0/30	1620/30	157.5/30	154.5/30
	birefringence (Δn)	0.068	0.085	0.106	0.124
	tenacity at break (g/de)	3.4	3.7	3.8	4.1
	elongation at break (%)	96	80	65	58
False twist crimping conditions	density (g/cm ³)	1.354	1.358	1.360	1.362
	number of false twists (T/M)	2750	2750	2750	2750
	False twist part draft (%)	12	8	5	3
	False twist part twist tension at 190°C. (gr/de)	0.104	0.098	0.099	0.102
False twist crimping conditions	heat treating part draft (%)	-17	-17	-17	-17
	heat treating part treating temperature (°C.)	230	230	230	230
	processing speed (m/min)	124	124	124	124

TABLE 10

Processing temperature (°C.)	Sample	Total percentage crimp		Dyeing properties		Torque of standard spindle (T/25 cm)	Density of standard spindle (g/cm ³)
		Standard spindle (TCs)	Crimp difference (ΔTC)	Standard spindle (Ds)	Dyeing difference (ΔD)		
170	Q	13.5	≤ 1	37.3	≤ 0.2	11	1.3859
	R	12.7	≤ 1	38.5	≤ 0.2	14	1.3860
	S	12.3	≤ 1	39.1	≤ 0.2	15	1.3858
	T	11.0	≤ 1	39.5	≤ 0.2	17	1.3862
190	Q	14.4	≤ 1	37.5	≤ 0.2	14	1.3912
	R	14.9	≤ 1	38.6	≤ 0.2	16	1.3914
	S	14.5	≤ 1	39.0	≤ 0.2	16	1.3910
	T	12.7	≤ 1	39.7	≤ 0.2	20	1.3911
210	Q	13.0	≤ 2	36.6	≤ 0.7	13	1.3954
	R	13.6	≤ 2	37.5	≤ 0.7	15	1.3960
	S	13.4	≤ 2	38.2	≤ 0.7	17	1.3957
	T	14.3	≤ 2	38.5	≤ 0.7	22	1.3962
220	Q	9.6	≤ 4	35.1	≤ 1.5	10	1.3988
	R	10.5	≤ 4	35.9	≤ 1.5	12	1.3991
	S	11.0	≤ 4	36.4	≤ 1.5	15	1.3989
	T	12.1	≤ 4	36.7	≤ 1.5	20	1.3988

Comparative Example 3.

The conditions for drawing the undrawn yarns obtained in Example 3, the properties of the resulting drawn yarns, and the conditions for false twist-crimping of the drawn yarns using a false twist crimping machine of the type shown in Figure 4 in which second heat-treating devices are arranged between 7, 7' and 8 are given in Table 11.

Ten spindles were used for the crimping of the drawn yarns, and the processing temperatures were varied from spindle to spindle by a maximum of $\pm 4^\circ\text{C}$. based on the standard spindle. Thus, ten false twist crimped

yarns were obtained. The total percentage crimp, dyeing properties and torques of the crimped yarns are shown in Table 12. It is seen from the table that in Samples U and V in which the birefringences of the drawn yarns are large as in the commercially available conventional drawn yarns of polyester, the torque becomes large at the temperatures (above 210°C .) at which the yarns have good total percentage crimp. Snarl occurs frequently when the crimped yarns are knitted. Furthermore, the dye exhaustion difference becomes large, and the non-uniformity of dyeing tends to occur among the spindles.

TABLE 11

Sample		U	V
Drawing conditions	heating means	hot roller	hot roller
	temperature ($^\circ\text{C}$.)	81	81
	draw ratio (x)	3.70	3.70
	draw speed (m/min)	800	800
	denier size (de/fil)	156.0/30	144.2/30
Physical properties of the drawn yarn	birefringence (Δn)	0.162	0.162
	tenacity at break (g/de)	5.4	5.4
	elongation at break (%)	28	28
	density (g/cm ³)	1.378	1.378
	number of false twists (T/M)	2750	2750
False twist crimping conditions	False twist part		
	draft (%)	4	-4
	twist tension at 190°C . (gr/de)	0.368	0.101
	heat treating part		
	draft (%)	-17	-17
	treating temperature ($^\circ\text{C}$.)	230	230
	processing speed (m/min.)	124	124

TABLE 12

Processing temperature (°C.)	Sample	Total percentage crimp		Dyeing properties		Torque of standard spindle (T/25 cm)	Density of standard spindle (g/cm ³)
		Standard spindle (TCs)	Crimp difference (Δ TC)	Standard spindle (Ds)	Dyeing difference (Δ D)		
210	U	11.5	≤ 2	43.5	≤ 0.7	25	1.3972
	V	14.4	≤ 2	42.6	≤ 0.7	27	1.3968
220	U	12.9	≤ 4	41.9	≤ 1.5	27	1.3996
	V	15.9	≤ 4	41.5	≤ 1.5	30	1.4001

WHAT WE CLAIM IS:—

1. A false twist-crimped yarn which is composed of filaments of a polyester containing at least 80 mole % of ethylene terephthalate units and which has a density of (d), measured as hereinbefore defined, of $1.3800 \leq d \leq 1.3950$ (g/cm³) and a total percentage crimp (TC), measured as hereinbefore defined, of $TC \geq 30$ (%).
2. A yarn according to claim 1 wherein the polyester is polyethylene terephthalate.
3. A yarn according to claim 1 substantially as hereinbefore described.
4. A modified false twist-crimped yarn which is composed of filaments of a polyester containing at least 80 mole % of ethylene terephthalate units and which has a density (d), measured as hereinbefore defined, of $1.3800 \leq d \leq 1.3950$ (g/cm³), a total percentage crimp (TC), measured as hereinbefore defined, of $TC \leq 20$ (%), and a torque, (Tq) measured as hereinbefore defined, of $Tq \leq 26$ (T/25 cm.).
5. A yarn according to claim 4 wherein the polyester is polyethylene terephthalate.
6. A yarn according to claim 4 substantially as hereinbefore described.
7. A process for producing a false twist-crimped polyester yarn by a false-twisting process which comprises false-twisting a multifilament yarn which is composed of filaments of a polyester containing at least 80 mole % of ethylene terephthalate units and which has a birefringence (Δn), measured as hereinbefore defined, of $0.030 \leq \Delta n \leq 0.145$ while heat setting the filament in the twisted state

at 160° to 210°C. at a draft (d_r) which satisfies the relation:

$$-250.\Delta n + 38 \geq d_r \geq -150.\Delta n + 17. \quad 40$$

8. A process according to claim 7 wherein the polyester multifilament yarn has a birefringence (Δn) of $0.06 \leq \Delta n \leq 0.135$.

9. A process according to claim 7 or 8 wherein the filaments have an intrinsic viscosity of 0.3 to 1.2. 45

10. A process according to any one of claims 7 to 9 wherein the heat setting temperature is 170° to 200°C.

11. A process according to any one of claims 7 to 10 wherein a modified false twist-crimped polyester yarn is produced by subjecting the false twist-crimped polyester yarn to a second heat setting at a temperature exceeding the temperature at which the yarn has been initially heat set. 50

12. A process according to claim 7 substantially as hereinbefore described with reference to and as illustrated in Figure 4 of the accompanying drawings. 55

13. A process according to claim 7 substantially as described in any one of the foregoing Examples. 60

14. A false twist-crimped yarn produced by a process as claimed in any one of claims 7 to 13. 65

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TABLE 12

Processing temperature (°C.)	Sample	Total percentage crimp		Dyeing properties		Torque of standard spindle (T/25 cm)	Density of standard spindle (g/cm ³)
		Standard spindle (TCs)	Crimp difference (ΔTC)	Standard spindle (Ds)	Dyeing difference (ΔD)		
210	U	11.5	≤2	43.5	≤0.7	25	1.3972
	V	14.4	≤2	42.6	≤0.7	27	1.3968
220	U	12.9	≤4	41.9	≤1.5	27	1.3996
	V	15.9	≤4	41.5	≤1.5	30	1.4001

WHAT WE CLAIM IS:—

1. A false twist-crimped yarn which is composed of filaments of a polyester containing at least 80 mole % of ethylene terephthalate units and which has a density of (d), measured as hereinbefore defined, of $1.3800 \leq d \leq 1.3950$ (g/cm³) and a total percentage crimp (TC), measured as hereinbefore defined, of $TC \geq 30$ (%).
2. A yarn according to claim 1 wherein the polyester is polyethylene terephthalate.
3. A yarn according to claim 1 substantially as hereinbefore described.
4. A modified false twist-crimped yarn which is composed of filaments of a polyester containing at least 80 mole % of ethylene terephthalate units and which has a density (d), measured as hereinbefore defined, of $1.3800 \leq d \leq 1.3950$ (g/cm³), a total percentage crimp (TC), measured as hereinbefore defined, of $TC \leq 20$ (%), and a torque, (Tq) measured as hereinbefore defined, of $Tq \leq 26$ (T/25 cm).
5. A yarn according to claim 4 wherein the polyester is polyethylene terephthalate.
6. A yarn according to claim 4 substantially as hereinbefore described.
7. A process for producing a false twist-crimped polyester yarn by a false-twisting process which comprises false-twisting a multifilament yarn which is composed of filaments of a polyester containing at least 80 mole % of ethylene terephthalate units and which has a birefringence (Δn), measured as hereinbefore defined, of $0.030 \leq \Delta n \leq 0.145$ while heat setting the filament in the twisted state

at 160° to 210°C. at a draft (d_r) which satisfies the relation:

$$-250.\Delta n + 38 \geq d_r \geq -150.\Delta n + 17. \quad 40$$

8. A process according to claim 7 wherein the polyester multifilament yarn has a birefringence (Δn) of $0.06 \leq \Delta n \leq 0.135$.

9. A process according to claim 7 or 8 wherein the filaments have an intrinsic viscosity of 0.3 to 1.2.

10. A process according to any one of claims 7 to 9 wherein the heat setting temperature is 170° to 200°C.

11. A process according to any one of claims 7 to 10 wherein a modified false twist-crimped polyester yarn is produced by subjecting the false twist-crimped polyester yarn to a second heat setting at a temperature exceeding the temperature at which the yarn has been initially heat set.

12. A process according to claim 7 substantially as hereinbefore described with reference to and as illustrated in Figure 4 of the accompanying drawings.

13. A process according to claim 7 substantially as described in any one of the foregoing Examples.

14. A false twist-crimped yarn produced by a process as claimed in any one of claims 7 to 13.

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