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HIGH TENACITY YARNS MADE FROM POLY-ETHYLENE TEREPHTHALATE, PARTICULARLY FOR SAILCLOTH

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8 Claims

ABSTRACT OF THE DISCLOSURE

Polyethylene terephthalate twisted yarn having an intrinsic viscosity of at least 0.87 of the polymer from which it is made retains the ability to shrink at least 10% after the twist liveliness has been removed by heating. Sailcloth and safety webbing are woven of this yarn and subsequently subjected to a shrinking operation to produce high strength fabrics.

This invention relates to improved high tenacity twisted or plied yarns and textiles made therefrom. More particularly the invention relates to improved plied yarns made from polyethylene terephthalate for use in sailcloth and/or safety belts for passenger aircraft and motor vehicles.

In a large number of industrial applications of textiles, e.g. sailcloth and safety belts, it is of prime importance that the filaments used therein have a high resistance to strains and stresses which occur in use as well as a high degree of dimensional stability. For these reasons it is known to use textile filaments having a high tenacity and any combination with other properties which impart good performance during use and in wear.

In certain industrial applications it is necessary to use twisted yarns or plied or folded yarns, i.e. two or more yarns which have been plied or twisted together, to facilitate processing or use. The ply or folding twist is generally in the opposite direction to any twist in the singles yarn. During processing such yarns display a twist liveliness which is undesirable. With conventional polyester yarns such twist liveliness can be deadened or removed by heating the yarn under suitable conditions at temperatures up to a temperature slightly below the melting temperature of the filaments. However, if it is desired that the yarn should have a relatively high shrinkage, i.e. a shrinkage of at least 10%, then the temperature at which twist liveliness (or the deadening of twist) can be reduced is determined by a maximum twist setting temperature which is below 80° C. If the twist setting temperature is increased above the stated temperature of 80° C. the resulting conventional yarn has a reduced shrinkage potential and this is undesirable for certain applications such as in sailcloth.

The present invention is based, to a significant extent, on the finding that if the polyester yarns are made from a polymer of an intrinsic viscosity in excess of 0.85, it is possible to raise the temperature for twist setting the yarn up to 110° C. and still obtain a yarn having a desirable residual shrinkage. This is particularly important, for example, in sailcloth fabric or safety belts where the high tenacity filaments can be shrunk to thereby impart a higher density to the fabric as well as giving it an increased stability. Moreover the elastic properties of the fabric are thereby desirably reduced.

According to one aspect of the invention, therefore, there is provided a twisted, plied or folded multifilament polyester yarn having a tenacity of at least 7 grams per denier, an intrinsic viscosity (in yarn form) of at least

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0.87 of the polyethylene terephthalate from which it is made, and a twist or plied twist of 2.5 to 15 turns per inch, the yarn being further characterized by the fact that its twist or plied twist has non-torque characteristics, i.e. no twist liveliness and yet which has a shrinkage of at least 10% when heated to a temperature of 180° C.

We also provide a process for making twisted singles or plied or folded yarns having a tenacity of at least 7 grams per denier and made from polyethylene terephthalate having an intrinsic viscosity of at least 0.87, which comprises melt-spinning the polyethylene terephthalate, maintaining the spun filaments below the spinneret at a high temperature followed by drawing the filaments at a temperature above 60° C. but below the melting point and reheating the filaments during drawing at least in the final part of that step at a temperature above 140° C., but below the melting point, twisting the resulting yarn or filaments or plying two or more of said filament yarns, by inserting from 2.5 to 15 turns per inch twist or folding or plying twist, again heating the yarns, for example on a package, at a temperature up to 110° C. under conditions such as to impart non-torque characteristics and so as to completely kill the torque properties of the yarn, finally heating the yarn at a temperature of at least 180° C. e.g. in fabric form, under conditions such as to bring about the potential shrinkage of at least 10%.

The final heating may be carried out on the twisted or plied yarns as such or preferably when made up into fabrics such as a sailcloth or safety belting or webbing in order to reduce bias stretch properties of the fabric due to the shrinkage of the yarns which bring about a tighter fabric construction. The plied yarns suitable for use in the invention are made from polyethylene terephthalate having an intrinsic viscosity of at least 0.87, a tenacity of at least 7 g.p.d. and a potential shrinkage before heating at a temperature above 150° C., of at least 10%. The filaments in these yarns have a high crystal-amorphous ratio and can be obtained by melt-spinning polyethylene terephthalate of the stipulated intrinsic viscosity followed by drawing, as set forth hereafter.

One process comprises meltspinning polyethylene terephthalate to give filaments of the required intrinsic viscosity, winding up the filaments with a tension in the spinning threadline to result in filaments having an optical birefringence between 0.003 and 0.15 and drawing the spun filaments at a temperature above 60° C. but below the melting point of polyethylene terephthalate, at least the final part of the drawing being carried out at a temperature above 140° C.

Another suitable process comprises meltspinning polyethylene terephthalate and drawing as described above but adjusting conditions in the spinning threadline so that the optical birefringence in the spinning threadline is less than 0.003 using draw ratios for drawing of at least 1:5.7, and temperatures during drawing in the range 80–225° C.

Specific spinning and drawing conditions are set forth in Table 1 using three different wind-up speeds after spinning and respectively three different draw ratios.

The properties of the resulting yarns are also given in Table 1.

Polyethylene terephthalate of I.V. 0.93 was melted by a screw extruder at about 290° C. through a separate filter at 302° C. and pumped through a spinneret having 24 holes of 0.018" diameter. The extruded filaments had an I.V. of about 0.87 (measured in a 1% solution of orthochlorophenol at 25° C.).

Immediately below the spinneret was a 24" long heated cylindrical shroud which was heated so that the temperature of the shroud was 340, 310 and 280° C. at

distances of 3, 12 and 24" respectively below the spinneret, through which the threadline passed.

The yarns were wound up at speeds as shown in Table 1 at a polymer throughput also as shown.

The spun yarn birefringence were also as shown.

The yarn was then drawn at 500 feet per minute using a heated feedroll at 65° C. and a hotplate at 215° C. then wound up.

The drawn yarn properties were as already stated as shown in Table 1.

It will also be seen from Table 1 that the shrinkage of the drawn yarn at 150° C. was in excess of 11% and the tenacity 8.65 grams per denier and above.

Samples of yarn were up-twisted and other samples of yarn were plied with a ply twist of 4 t.p.i. warp and 2½ t.p.i. weft. The samples of twisted yarn and plied yarn were heated in order to kill their twist liveliness at a temperature of 110° C. for 20 minutes. These yarns retained their tenacity at well above 7 grams per denier. They showed no twist liveliness but they still had a shrinkage in excess of 10%. These yarns were eminently suitable for the manufacture of sailcloth which could be heat-set and the sett thereby increased to result in a sailcloth fabric in which the stretch in the bias direction has been practically eliminated.

Suitable yarns which may be used are e.g.: 50 denier 24 filaments with 10 turns per inch, 125 denier 24 filaments with 7.5 turns per inch, 250 denier 48 filaments with 5 turns per inch, 2/250 denier 48 filaments each 4 turns per inch, 3/250 denier 48 filaments each 3 turns per inch, 1000 denier 192 filaments each 2.5 turns per inch, 2/1000 denier 192 filaments each 2.5 turns per inch.

It should be appreciated that yarns made from polyethylene terephthalate of normal or lower intrinsic viscosity between 0.6 and 0.8 also display shrinkage properties when heated at a high temperature of about 150° C. but the shrinkage obtained is about 10% or less.

If, however, the intrinsic viscosity of the polyethylene terephthalate from which the yarns have been made, is above 0.85, preferably at least 0.87, shrinkage increases considerably and rises unexpectedly to values in excess of 10 to about 16%, when spun and drawn under comparative conditions.

The accompanying graph shows the effect of intrinsic viscosity and shrinkage of yarns spun from polyethylene terephthalate when heated at a temperature of 150° C. It will be seen that there is a steep, unexpected rise in the shrinkage when the intrinsic viscosity of the polymer from which the yarns are made has an intrinsic viscosity of at least 0.87.

The difficulty of stabilizing high intrinsic viscosity yarns is a surprising development which although a disadvantage in some applications e.g. for the reinforcement of rubber articles, can be used to advantage in other applications, in particular sailcloth and safety belting where consolidation of the fabric after weaving is desirable in order to reduce bias extension in the sail or belt.

During the manufacture of sailcloth or safety belting it is necessary to twist set the yarn, to enable the fabric to be woven. The effect of twist setting is to reduce the potential shrinkage to a lower level, and hence the full degree of consolidation cannot be achieved. Two possibilities exist with yarns made from polymer of normal intrinsic viscosity. The first is to reduce the twist setting temperature from 110° C. to 80° C. to give a relatively high level of potential shrinkage in the yarn at the expense of fully killing the liveliness of the yarn. The second is to twist-set at 110° C. killing the twist but reducing the potential shrinkage.

With yarns made from polymer of high intrinsic viscosity it is possible to employ the higher twist setting temperature, killing the twist completely but still retaining a high potential shrinkage in the yarn. The normal temperature employed during shrinking of a sailcloth

made from polyethylene terephthalate yarn Terylene (registered trademark) is 180° C. and the following table shows the potential shrinkage at this temperature for Type A (usual I.V.) and Type B (I.V. of at least 0.87) yarn after twist setting at 80° C. and 110° C., for a range of twist employed on yarns used in sailcloth manufacture.

TABLE

Yarn type	Twist setting temperature, ° C.	Twist (t.p.i.)	Percent shrinkage at 180° C.	Yarn liveliness
B (I.V. 0.90)-----	80	2.5	15.1	No
		5.0	15.8	Yes
		7.5	15.7	Yes
	110	2.5	10.0	No
		5.0	10.7	No
		7.5	11.2	No
A (I.V. 0.65)-----	80	2.5	12.9	Yes
		5.0	13.2	Yes
		7.5	13.9	Yes
	110	2.5	8.0	No
		5.0	8.7	No
		7.5	8.6	No

NOTE.—"Yes" denotes yarn still lively. "No" denotes yarn is dead, i.e. shows no twist liveliness.

These results show that higher shrinkage of the yarns can be obtained with Type B yarns.

We have found that sailcloth particularly those for competitive sailing require high quality fabrics which are woven to give higher setts. It should be noted that the finished sett will vary with any particular finishing routine used and that unless the fabric, before finishing, is perfectly flat, with even selvages, it will be difficult to control shrinkage unless extra warp tension is applied to produce a flat fabric. It is important, therefore, that there should be close cooperation between the weaver and the finisher to ensure that consistent finished setts are achieved resulting in flat fabrics.

Air permeability is also important and we have found that it should be as low as possible and for non-resin finished fabrics of high sett this should be around 0.2 ccs./sq. cm./sec./cm. head of water.

We have concluded that for a sailcloth to have the lowest extension under load and residual extension after the removal of a load (measured in a grab test on an Instron Tensile Tester on a sample in the bias direction of the cloth) it should have as tight a finished sett as possible, i.e. a high cover factor, assuming the same finishing routine is used. The tightness of this sett is governed by mechanical considerations with regard to the capabilities of the loom and the shrinkage is induced in the fabric during finishing.

The method of calculating cover factor for the warp and weft yarns is as follows:

$$\text{Cover Factor (warp)} = \frac{\text{ends/inch} \sqrt{\text{resulting warp denier}}}{73}$$

$$\text{Cover Factor (weft)} = \frac{\text{picks/inch} \sqrt{\text{resulting weft denier}}}{73}$$

For a square sett fabric the tightness of weave is equal to the sum of the warp and weft cover factors. For an off square fabric this is only approximately true, consequently the warp and weft cover factors are given separately in the table.

It should be appreciated that most commercial sailcloths are treated with resin and that the amount and type of resin used may have a considerable effect on mechanical test results. The effect of most resin treatments is to give substantially improved residual extension figures, but since the effect of a resin treatment decays during the life of a sail, this is not an acceptable way of

improving the performance of a fabric which does not have the required initial sett, i.e. construction and properties.

We have found that using our yarns a cover factor of 35 to 45 may be obtained using singles yarn in cloth weighing up to 8 oz. preferably 4 to 8 ozs. inclusive. Cover factors between 40 to 50 may be obtained using our plied yarns in fabrics weighing over 8 ounces, preferably 8 to 20 ounces per square yard.

COMPARATIVE EXAMPLE

For purposes of comparison samples of yarn were prepared using a polymer of normal intrinsic viscosity which in yarn form was 0.63. The yarn was melt-spun and wound up at 3,000 feet per minute. The yarn was wound up, drawn and plied as set out below.

Polymer, I.V.	0.67.
Spinning temp.	295° C.
Spinneret	50/.018".
Wind-up speed	3,000 ft./min.
Spun denier	1,234 (50 filaments).
Spun yarn birefringence	.0046.
Spun yarn shrinkage	46%.
Draw speed	500 ft./min.
Feed roll temp.	65° C.
Plate temp.	200° C.
Plied on drawframe, 4 times:	
Draw ratio	4.50; 4.78; 5.06; 5.34.
Denier	1,131; 1,075; 1,014; 961.
Tenacity, g./d.	6.7; 7.4; 7.8; 8.8.
Extension, percent	12.5; 9.8; 7.8; 7.4.
150° C. shrinkage, percent	8.7; 9.0; 8.9; 8.9.
5% modulus, g./d.	99; 110; 111; 124.

The resulting shrinkage at 150° C. was 9% and below. Samples of this yarn were used in the manufacture of sailcloth as set forth in the following comparative example.

Two sailcloths were woven from yarns of high intrinsic viscosity (0.88) and from normal (0.63) I.V. using 4/250 denier yarns.

The yarns were twisted to 4 t.p.i. in the warp and 2½ t.p.i. in the weft and twist set.

The yarns were then woven to identical constructions 44 x 35 threads/inch.

The resulting fabrics were both subjected to identical commercial finishing conditions. On a laboratory examination it was found that fabric with the high I.V. yarn had shrunk more than fabric woven from normal I.V. yarn. This was reflected in the different setts obtained.

High I.V. 49.0 x 39.2 threads/inch
Normal I.V. 48.6 x 38.0 threads/inch

The consequence of this is that the fabric woven from high I.V. is more resistant to stretch in the bias direction and is also less permeable to air than the fabric woven from normal I.V. yarn. Some of the different properties are tabulated below.

	High I.V. (0.88)		Normal I.V. (0.68) (comparative)	
	Warp	Weft	Warp	Weft
Grey sett, threads/inch	44.0	35.0	44.0	35.0
Finished sett, threads/inch	49.0	39.2	48.6	38.0
Percent shrinkage	12	11.4	8.5	10.4
Air permeability:				
Ccs./cm. ² /sec. per cm. head				
of water	0.1		0.4	
Cover factor	41.5		40.7	

BIAS EXTENSION UNDER LOAD AND RESIDUAL EXTENSION AFTER THE REMOVAL OF A LOAD

	High I.V. (0.88)	Normal I.V. (0.63) (comparative)
Percent extension under load at—		
15 kg./inch	7.6	8.6
20 kg./inch	9.2	10.2
25 kg./inch	10.9	11.9
30 kg./inch	12.4	13.5
35 kg./inch	13.8	14.9
10 Immediate residual extension after the removal of a load at—		
15 kg./inch	1.6	1.6
20 kg./inch	2.9	3.4
25 kg./inch	4.2	5.0
30 kg./inch	6.1	6.1
35 kg./inch	7.6	7.6
15 Residual extension from load of 35 kg./inch after relaxation for—		
1 minute	2.9	3.9
5 minutes	1.9	3.1
15 minutes	1.4	2.9
30 minutes	1.3	2.6
60 minutes	1.2	2.6

In another comparative test two samples of high-extension safety webbing were woven to the same construction, one from 0.63 I.V. polyethylene terephthalate yarn having a tenacity of 6.3 g.p.d. and an extension at break of 11% and the other from .88 I.V. polyethylene terephthalate yarn having a tenacity of 9.0 g.p.d. and an extension at break of 10.5%. The webbings showed the following properties before and after being subjected to identical commercial finishing materials.

	High I.V.	Normal I.V.
Tensile strength, lbs. loomstate	4,620	4,520
Tensile strength, lbs. finished	4,379	3,890
Extension at 1,500 kg. percent loomstate	12	12
Extension at 1,500 kg. percent finished	39	32.5

The construction of the high I.V. webbing was as follows:

Weave 2/2 broken twill weaving 2 ends as 1
Loomstate weight 53.5 g./m. Finished 67.3 g./m.
Total ends 361 of 1,000 denier
Weft 28 picks of 750 denier PHD yarn.

It is often desirable to provide safety webbing having an extension greater than 35% at a load of 1500 kg., and the above-described 0.88 I.V. webbing is admirably suited for this purpose. It is not possible to increase the extension at 1500 kg. for the 0.63 I.V. yarn appreciably by finishing at a higher temperature since this will result in degradation of the yarn and the webbing will fall below specification on strength.

A different form of high I.V. webbing having a lower-extension under load has the following construction:

Weave: Face 5/1. Back 1/5. Binder 3/3. Gut 1/1.
Loomstate weight: 51 g./yd. Finished weight: 59 g./yd.
Face warp: 115 ends of 1,000 denier high tenacity (9.0 g.p.d.) polyethylene terephthalate yarn 2½ S turn/inch.
Back warp: 116 ends of the same yarn.
Gut or wadding warp: 55 ends of the same yarn.
Thin binder or stitching warp: 54 ends of 2/250 denier high tenacity polyethylene terephthalate 3½ Z turns/inch ply twist.
Thick binder or stitching warp: 54 ends of 1,000 denier high tenacity polyethylene terephthalate 2½ S turns/inch.

TABLE 1.—SPINNING AND DRAWING CONDITIONS WITH RESULTING YARN PROPERTIES

Polymer R.V. (1% DCA)	2.4.
Filter temp., ° C.	302.
Extruder temp., ° C.	288/293.
Dowtherm temp., ° C.	292.
Shroud temp., ° C. ¹	340–320–280. ²
Wind up speed, ft./min.	2,300; 2,540; 2,800.
Polymer throughput, lb./hr.	54.9; 57.0; 61.5.
Yarn I.V. (8% OCP)	.87; .91; .91.
Spun birefringence	.0035; .0045; .0055.
Draw roll temp., ° C.	65; 65; 65.
Draw plate temp., ° C.	215; 215; 215
Draw speed, f.p.m.	500; 500; 500.
Draw ratio	5.34; 5.15; 4.97.
Denier	1,003; 985; 1,003.
Tenacity (T), g./d.	8.65; 8.85; 8.92.
Extension (E), percent	10.0; 10.0; 10.6.
Tensile factor, TE ^{1/2}	27.4; 28.0; 29.0.
150° C. shrinkage, percent	11.4; 11.7; 11.5.
5% modulus g./d.	105; 103; 106.
Wt. of yarn drawn, lb.	2,010; 1,005; 5.
Draw rolls, laps/lb.	.11; .34; .4.
Drawn threadline, breaks/lb.	.001; .002; 0.
Drawn yarn birefringence	.199; .201; .200.

¹ Shroud 24" long.² Air temperature 3", 12" and 24" below the spinneret.

What we claim is:

1. A multifilament yarn with a tenacity of at least 7 grams per denier, having an intrinsic viscosity, in yarn form, of at least 0.87 of the polyethylene terephthalate from which it is made and having a twist of 2.5 to 15 turns per inch, further characterized in that the twist has non-torque characteristics and therefore no twist liveliness and yet which has a shrinkage of at least 10% when heated to a temperature of 180° C.

2. A multifilament yarn according to claim 1 having from 24 to 192 filaments each and a singles yarn denier between 50 and 1,000.

3. A sailcloth fabric woven from a twisted singles yarn as claimed in claim 1 having a cover factor between 35 to 45 inclusive and the cloth having a weight between 4 and 8 ounces per square yard, inclusive.

4. A sailcloth fabric woven from a plied yarn as claimed in claim 1 having a cover factor between 40 and 50 inclusive and the fabric having a weight of between 8 and 20 ounces per square yard, inclusive.

5. A safety webbing woven from yarns as defined in claim 1, said webbing having an extension greater than 35% at a load of 1500 kg.

6. A process for making a yarn as claimed in claim 1 having a tenacity of at least 7 grams per denier and made from polyethylene terephthalate having an intrinsic viscosity of at least 0.87, comprising melt-spinning the polyethylene terephthalate, maintaining the spun filaments below the spinneret at a high temperature followed by drawing the filaments at a temperature above 60° C. but below the melting point and reheating the filaments during drawing at least in the final part of that step at a temperature above 140° C., but below the melting point, twisting the resulting yarn, plying two or more of said filament yarns by inserting from 2.5 to 15 turns per inch twist, again heating the yarns at a temperature up to 110° C. under conditions such as to impart non-torque characteristics and so as to completely kill the torque properties of the yarn, and finally heating the yarn at a temperature of at least 180° C., e.g. in fabric form, under conditions such as to bring about the potential shrinkage of at least 10%.

7. A process according to claim 5 in which the melt-spun filaments are heated in a shroud immediately below the spinneret, the included air temperature of which is maintained between 280 to 340° C., 3 to 24 inches below the spinneret face.

8. A process according to claim 5 in which the filaments are drawn at a temperature above 60° C., and then heated on a plate above 200° C.

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