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METHOD OF PREPARING SYNTHETIC CONTINUOUS MULTIFILAMENT YARNS BY THE COUPLED SPINNING-DRAWING PROCESS

Isao Hamana, Yoshio Fujiwara, and Hirofumi Yoshikawa, Iwakuni, and Kanzi Shiokawa, Seijun Kato, and Testuo Nozawa, Mihara, Japan, assignors to Teijin Limited, Osaka, Japan

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ABSTRACT OF THE DISCLOSURE

A method of preparing oriented synthetic continuous multifilament yarns by the coupled spinning-drawing process, which comprises interlacing a bundle of as-spun synthetic continuous multifilaments so that an interlacing degree of 0.1–2.0 per meter of the bundle length is attained, and subsequently drawing the interlaced bundle at a prescribed stretch ratio.

This invention relates to a method of preparing oriented synthetic continuous multifilament yarns by the coupled spinning-drawing process.

Commercially available oriented synthetic continuous multifilament yarns are usually prepared by wet-spinning, dry-spinning or melt-spinning synthetic linear polymeric substances into multifilaments, winding undrawn multifilament yarns into a package, and subsequently unwinding and drawing the yarns. Since the spinning and drawing steps are conducted separately in this conventional process, this process may be called a "split" process.

The need for increased yarn production at reduced manufacturing costs has led to development of processes where the spinning and drawing steps operate continuously, namely these steps are not separated by an intermediate packing step. Such process is called a "coupled" process or a "coupled spinning-drawing" process.

In the preparation of synthetic multifilament yarns, especially polyester multifilament yarns and polyamide multifilament yarns by the coupled spinning-drawing process, if conditions customarily adopted in the spinning and drawing steps of the conventional split process are directly applied, it is very difficult to accomplish the drawing by a stable operation because of occurrence of fluffs or yarn breakage during the drawing. Further, the quality of the resulting yarns is poor and they are of little practical value.

It is an object of this invention to provide a method of preparing synthetic continuous multifilament yarns where such defects of the coupled spinning-drawing process are overcome and it is possible to prepare synthetic continuous multifilament yarns efficiently.

Another object of this invention is to provide a novel coupled spinning-drawing process in which the drawing operation can be performed in a very stable state at a high stretch ratio and high tenacity synthetic continuous multifilament yarns excellent in orientation can be prepared conveniently.

Further objects and advantages of this invention will be apparent from the following description.

According to this invention, the above objects and advantages can be attained by a method of preparing oriented synthetic continuous multifilament yarns by the coupled spinning-drawing process, which comprises interlacing a bundle of as-spun synthetic continuous multifilaments so that an interlacing degree of 0.1–2.0 per meter of the bundle length is attained, and subsequently drawing the interlaced bundles at a prescribed stretch ratio.

The method of this invention may be applied to bundle of synthetic continuous multifilaments spun by any of the wet-spinning, dry-spinning and melt-spinning processes. These bundles of continuous multifilaments may be those spun from one spinneret having a plurality of nozzles or those formed by gathering bundles of continuous multifilaments spun from two or more of such spinnerets.

Synthetic continuous multifilaments may be formed by applying a suitable spinning technique chosen from the above-mentioned spinning processes to optional fiber-forming crystalline linear polymers, for instance, polyesters, polyamides, acrylic polymers, vinyl chloride polymers, acetalized vinyl alcohol polymers and polyolefins.

The method of this invention can be particularly effectively applied to bundles of continuous multifilaments obtained by melt-spinning the following polymers:

(a) polyethylene terephthalate having a fiber-forming degree of polymerization, or a fiber-forming copolyester in which at least 80 mole percent of the recurring units are ethylene terephthalate units;

(b) polyethylene-2,6-naphthalate, or a fiber-forming copolyester in which at least 80 mole percent of the recurring units are ethylene-2,6-naphthalate units; and

(c) nylon-6, nylon-6,6-, or a fiber-forming copolyamide in which at least 80 mole percent of the recurring units are ε-caproamide or hexamethylene adipamide units.

Of course, the method of this invention may be applied advantageously to bundles of continuous multifilaments of fiber-forming synthetic polymers other than those mentioned above.

Techniques of preparing non-bulky multifilament yarns, i.e., interlaced yarns, from bundles of such continuous multifilaments by subjecting a continuous multifilament bundle unnder tension to the action of a fluid such as a high speed air stream, e.g., jet stream, and interlacing randomly two or more of the filaments in the bundle without imparting any true twist to the yarn bundle have already been known in the art from, for instance, the specification of British Pat. No. 924,089.

According to the teachings of such British specification, the degree of coherency in the filaments of the resulting interlaced yarn is determined by the hook drop test. Also in this invention, the interlacing degree is determined by this test method.

More specifically, the interlacing degree is determined in the following manner:

A sample of a synthetic continuous multifilament bundle is clamped in the vertical position under the tension provided by a weight in grams which is 0.20 times the yarn denier (but not greater than 100 grams). A weighted hook having a total weight in grams numerically equal to the mean denier per filament of the bundle (but weighing not more than 10 grams) is inserted through the bundle at an optional point and lowered at a rate of 1–2 cm./sec. until the hook weight is supported by the bundle and the falling of the hook stops. The point where the falling of the hook stops is designated as stop point (P) (one interlacing). The above hook test is effected in a similar manner by lowering the hook from the point just below stop point (P). These procedures are repeated, and the number of the stop points (P) along the length of 1 meter of the bundle is counted and this number defined as the "interlacing degree." (See p. 2, lines 44–57 of the specification of British Pat. No. 924,089).

In accordance with this invention, a bundle of synthetic continuous multifilaments spun from a spinneret such as described above is interlaced by an optional method, for instance, the method disclosed in the above British specification, to form a nonbulky gathered filament bundle having an interlacing degree of 0.1–2.0 per meter of the bundle, preferably 0.3–1.0 per meter of the bundle.

Usually, the interlacing is conducted, instead of ordinary true twisting, for imparting gathering property or coherency to continuous multifilament yarns. The interlacing according to this invention is distinguished from such interlacing in the point that the interlacing degree is much lower than that attained in such conventional interlacing.

As a result of experiments it has been found that when the interlacing degree is less than 0.3, especially less than 0.1, the gathering property or coherency of the filaments is poor, and therefore, fluffs or yarn breakages frequently occur during the drawing, with the result that it is impossible to conduct the drawing smoothly and stably. It has also been found that when the interlacing degree is greater than 1, especially greater than 2, although the gathering property or coherency of the filaments can be improved, the drawing tension imposed on the filaments becomes non-uniform resulting in unstable fixation of the draw point, and at the same time the undrawn filaments tend to be flawed or scratched with reduction of the drawability. In short, as shown in the Examples and Comparative Examples given hereinbelow, when the interlacing degree is lower than 0.1 per meter of the bundle or greater than 2.0 per meter of the bundle, a maximum draw ration applicable to the continuous multifilament bundle is reduced.

According to research, it has also been found that in interlacing bundles of continuous multifilaments spun from one or more spinnerets (undrawn filament bundles) so as to attain the interlacing degree within the above range, it is especially advantageous to perform the interlacing by sujecting the continuous multifilament bundle to the action of a swirling stream of fluid by employing a fluid false twister. In this case, the continuous multifilament bundle is not only interlaced at an interlacing degree within the above range but also false-twisted appropriately. Accordingly, the bundle is provided with such gathering property or coherency as will make it possible for each filament to undergo uniform drawing tension during the subsequent drawing step.

Such interlacing procedure involving the false twisting effect may be conveniently accomplished by employing a fluid projecting apparatus capable of causing a swirling stream of fluid such as air to collide against the filament bundle to thereby exert the false twisting and interlacing actions to the filament bundle. Preferable examples of such fluid projecting apparatus or fluid false twister are illustrated, for instance, in FIGS. 21 and 22 of the specification of U.S. Pat. No. 3,009,309.

It is preferred that such apparatus is so designed that the sectional area of the yarn passage is 4.5–10 times the sectional area of the fluid projecting passage at the point where the yarn crosses the fluid stream from the

projecting opening. It is also preferred to cause the fluid stream to strike against the multifilament bundle vertically in relation to the forwarding direction of the bundle or at an angle of an inclination of from −30 to 30°, preferably from −15–15°, from the direction vertical to the bundle forwarding direction. Such apparatus arrangement makes it possible to impart both the interlacking and false twisting effects to the multifilament bundle very efficiently.

It is also advantageous to design such fluid false twister so that at least 50%, preferably at least 60%, of the fluid projected from the opening will participate in false-twisting the continuous multifilament bundle and that less than 40%, preferably less than 30%, of the fluid projected from the opening will exert the action of interlacing the multifilament bundle.

When such fluid false twister is used, occurrence of a turbulent zone in the yarn passage of the apparatus is relatively low and therefore, the multifilament bundle is not excessively interlaced; namely the interlacing degree is easily and stably adjusted within the above-mentioned range intended in this invention by controlling the rate or pressure of the fluid to be projected into the bundle passage from the fluid opening.

In the interlacing step, the temperature of fluid, e.g., air, may be room temperature, or the fluid may be heated to a suitable temperature. It is preferred to maintain the tension on the bundle passing through the yarn passage of the apparatus at about 0.1 to 0.4 g./d.

In this invention it is also preferred to treat the continuous multifilament bundle spun from the spinneret with an oiling agent prior to the above-mentioned interlacing treatment. In this oiling treatment, especially good results are obtained when the treatment is conducted so that the amount of water applied to the multifilament bundle will be not greater than 1.2% by weight (based on the weight of the filament bundle containing the equilibrium amount of water at 25° C. and a relative humidity of 65%). The smaller the amount of applied water, the better results are obtainable, and it is most desired to conduct the oiling treatment under such conditions that the amount of applied water will be substantially zero.

Any of the so called spinning oils used for spun synthetic multifilaments after cooling and solidification thereof may be used in this invention. As such oiling agents there may be exemplified non-ionic surfactants, and mixtures of non-ionic surfactants with neutral liquid oils such as mineral oils, animal oils, vegetable oils, higher fatty acid esters, polyglycol derivatives and silicone oils. It is preferred to use nonionic surfactants in the state diluted with inert organic solvents such as trichloroethylene or with neutral liquid oils such as exemplified above. Of course, it is possible to use such neutral liquid oils in the state diluted with, or emulsified in, such inert organic solvents.

In the conventional oiling treatment of spun continuous multifilament bundles, these non-ionic surfactants and/or neutral liquid oils are frequently used in the form of aqueous emulsions. In this invention, however, since good results are obtained by adjusting the amount of applied water to not greater than 1.2% by weight as described above, the use of aqueous emulsion is not preferred.

When water is applied to the continuous multifilament bundle in an amount exceeding 1.2% by weight, during the subsequent interlacing step and/or drawing step, heating unevenness occurs between the peripheral portion and internal portion of each filament or between the outer layer and inner layer of the filament bundle, with the result that uniformity in the structural characteristics in the sectional direction of each filament (for instance, the crystal distribution in the sectional direction) and uniformity in physical properties based on such structural characteristics cannot be attained, and as a result, attainment of a uniform drawing effect cannot be expected.

In accordance with this invention, bundles of spun synthetic continuous multifilaments, preferably after the above-mentioned oiling treatment, are interlaced so that the bundles will have an interlacing degree of 0.1–2.0, preferably 0.3–1.0, and thereafter, the so interlaced multifilament bundles are drawn at a prescribed stretch ratio, optionally after they have been preheated to suitable drawing temperatures. By such procedures, the coupled spinning-drawing process may be accomplished very smoothly. The above preheating treatment is not always necessary and it is sufficient to conduct the drawing operation at suitable temperatures depending on the kind of synthetic multifilament to be drawn. In many cases, however, it is advantageous to carry out the preheating treatment, because it makes it possible to simplify the drawing apparatus and facilitates the drawing operation. Preferable preheating temperatures are within a range of from 80 to 110° C. in the case of polyester filaments, and in the case of polyamide filaments it is preferred to conduct the preheating at temperatures not higher than 80° C., especially temperatures ranging from 60 to 30 °C. It is desired to perform the drawing operation at such temperatures.

In this invention, especially good results are obtained, as described above, by subjecting a bundle of as spun synthetic continuous multifilaments to the oiling treatment so that the amount of applied water will be not greaer than 1.2% by weight based on the filament weight, interlacing the bundle so that it will have an interlacing degree of 0.1–2.0, preferably 0.3;1.0, while false-twisting it by employing a fluid false twister such as described above, and subsequently drawing the so interlaced bundle at a prescribed stretch ratio, optionally after the preheating treatment.

When the false-twisting-interlacing is conducted after the oiling treatment, the oiling agent is uniformly distributed on each filament of the multifilament bundle, and the false twisting-interlacing operation gives a uniform gathering property or coherence to the entire bundle of multifilaments, synergistically with the oiling effect. Thus, a maximum stretch ratio can be increased and it is possible to conduct the drawing operation smoothly and stably, with the result that a high tenacity multifilament yarn of high quality and high orientation can be manufactured by the coupled spinning-drawing process.

In general, it is preferred to conduct the drawing operation at temperatures ranging from the second transition temperature of the multifilament to a temperature higher by less than 50° C., preferably by less than 30° C., than the second transition temperature of the multifilament.

In the case of, for instance, polyester or polyamide filaments, it is preferred to conduct the drawing at a stretch ratio exceeding 4.2. The drawing may be performed in one stage or in two or more stages.

Any of the known drawing devices may be used in this invention. For instance, drawing pins, plate heaters, heating rolls and the like may be used, but it is preferable to conduct the drawing by employing a roll system which may be heated or not. When a heater is adopted, it is desired to employ a heater of the non-contact type, for example, a slit heater.

In accordance with the method of this invention, synthetic multifilament bundles can be drawn at such a high draw ratio and such a high drawing efficiency by the coupled spinning-drawing process, as by the conventional split process including an intermediate packing step.

The method of this invention may be applied to the preparation of drawn multifilament yarns for clothing or industrial uses which consist of several to several thousand gathered monofilaments, and is especially suitable for preparing drawn synthetic continuous multifilament yarns having a total denier of from scores to several thousands and consisting of scores to several thousands of monofilaments.

The method of this invention can be advantageously applied to the manufacture of multifilament yarns for interior decoration or for industrial uses, such as carpet yarns, cords for rubber reinforcement, ropes for fisheries, etc.

This invention will now be explained in more detail by referring to Examples and Comparative Examples.

EXAMPLES 1–9 AND COMPARATIVE EXAMPLES 1–10

Granular poly-ε-caproamide having a number average molecular weight of about 25,000 was melt-spun at a temperature of 265° C. and a spinning rate of 350 m./min., and the cooled and solidified spun multifilament yarn was treated with a spinning oil and taken up by a godet roll. The taken-up multifilament yarn bundle (about 3550 denier/134 filaments) was directly forwarded to a drawing device comprising feed rolls and drawing rolls without being wound on a spool or the like. Thus, an oriented polycaproamide multifilament yarn was manufactured by one-stage drawing.

As the spinning oil a mixture composed of 70 parts by weight of trimethyl propane tridecanoate (higher fatty acid ester) and 30 parts by weight of polyoxyethylene nonyl phenyl ether (nonionic surfactant) was used. This oiling agent was used as it was or after it had been dispersed into trichloroethylene or water, so as to vary the amount of applied water after the oiling treatment as indicated in Table 1. Between the oiling treatment apparatus and the godet roll, air fluid was caused to collide against the running multifilament yarn by employing a fluid false twister to impart an interlacing degree shown in Table 1 to the multifilament yarn. For comparison, an experiment where the multifilament yarn was not interlaced was conducted.

As the fluid false twister an apparatus having a structure similar to the structure of the fluid false twister illustrated in FIG. 22 of the specification of U.S. Pat. No. 3,009,309 was used. In the fluid false twister employed, the yarn passage had a diameter of 2.5 mm., and the sectional area of the yarn passage was 6 times the sectional area of the projected fluid passage at the point where the multifilament yarn crossed the fluid projected from the opening. The interlacing degree was varied as indicated in Table 1 by adjusting the pressure of the fluid projected to the yarn passage and the tension on the multifilament yarn passing through the device.

Prior to the drawing, the multifilament yarn was preheated to 50° C.

During the drawing, a maximum stretch ratio was determined. The maximum stretch ratio used herein is a value determined in the following manner:

The interlaced multifilament yarn is forwarded to the drawing device where the peripheral speed of feed rolls is maintained at 350 m./min. The peripheral speed of drawing rolls is increased at a rate of 10 m./sec, and the stretch ratio at which the multifilament yarn is completely broken by such gradual acceleration of the peripheral speed of drawing rolls is designated as the maximum stretch ratio.

After the maximum stretch ratio was determined in the above-mentioned manner, the multifilament yarn was drawn at a stretch ratio 0.9 times as high as the maximum stretch ratio. At this stretch ratio the drawing could be conducted very smoothly and stably. The tenacity and elongation of the so drawn multifilament yarn were measured. The stretch ratio 0.9 times as high as the maximum stretch ratio is an optimum stretch ratio for conducting the drawing industrially under stable conditions with minimum occurrence of yarn breakages.

Separately, the interlaced multifilament yarn was drawn at a stretch ratio of 4.2 to evaluate the drawability of the yarn.

Experimental conditions and results are shown in Table 1.

TABLE 1.—INTERLACING OPERATION

	Dispersion medium for oiling agent	Amount of applied water (wt. percent)	Fluid pressure (kg./cm.²)	Yarn tension (g./d.)	Interlacing degree (per meter)	Maximum stretch ratio	Number of yarn breakages at stretch ratio of 4.2 (per kg.) ¹	Tenacity (g./d.)	Elongation (percent)
Comparative Example 1	Nil	0.0	0	0.35	0.0	4.35	0.850	5.80	39.1
Example 1	Nil	0.0	ca. 3.5	0.35	ca. 0.8	5.09	0.005	7.75	30.1
Comparative Example 2	Trichloroethylene	0.0	0	0.35	0.0	4.36	0.920	6.02	36.5
Example 2	do	0.0	ca. 1.5	0.35	ca. 0.1	4.77	0.025	6.99	30.5
Example 3	do	0.0	ca. 2.5	0.35	ca. 0.3	4.98	0.011	7.56	29.2
Example 4	do	0.0	ca. 3.5	0.35	ca. 0.8	5.14	0.003	7.82	29.5
Example 5	do	0.0	ca. 4.5	0.35	ca. 1.0	5.03	0.008	7.71	30.6
Example 6	do	0.0	ca. 5.5	0.35	ca. 1.5	4.71	0.069	6.93	31.1
Comparative Example 3	do	0.0	ca. 5.5	0.10	ca. 4.0	4.29	0.720	5.58	40.3
Comparative Example 4	Water	0.42	0	0.35	0.0	4.22	(²)	5.55	40.8
Example 7	do	0.42	ca. 3.5	0.35	ca. 0.8	4.89	0.025	7.25	28.0
Comparative Example 5	do	0.42	ca. 5.5	0.15	ca. 3.5	4.25	0.750	5.89	38.9
Comparative Example 6	do	1.17	0	0.35	0.0	4.13		5.39	42.8
Example 8	do	1.17	ca. 3.5	0.35	ca. 0.8	4.78	0.043	7.00	30.2
Comparative Example 7	do	1.17	ca. 5.5	0.15	ca. 3.5	4.21	(²)	5.49	41.5
Comparative Example 8	do	1.45	0	0.35	0.0	3.93		4.85	50.1
Example 9	do	1.45	ca. 3.5	0.35	ca. 0.8	4.41	0.630	5.83	38.2
Comparative Example 9	do	1.45	ca. 5.5	0.10	ca. 4.0	3.95		4.87	49.2
Comparative Example 10	do	3.51	0	0.35	0.0	3.83		4.58	55.5

¹ In case the number of yarn breakages per kg. of the yarn is less than 0.07, it may be said that the drawability is good.

² Drawing impossible—Since the stretch ratio of 4.2 was very close to the maximum stretch ratio, yarn breakages occurred very frequently and it was impossible to conduct the drawing operation continuously in the stable state.

As is seen from the results shown in Table 1, when the interlacing degree is within a range specified in this invention, namely 0.1–2.0, preferably 0.3–1.0, per meter of the multifilament yarn (Examples 1–9), the maximum stretch ratio is higher than in the case where the interlacing degree is outside the range (Comparative Examples 1–10). Accordingly, the stretch ratio 0.9 times as high as the maximum stretch ratio is naturally higher, and therefore, it is possible to obtain a multifilament yarn of a higher tenacity under stable operation. Further, among experiments where the interlacing degree was within a range of from 0.2 to 2.0 per meter of the multifilament yarn (Examples 1–9), experiments where the amount of applied water was not greater than 1.2% by weight (Examples 1–8) gave a higher maximum stretch ratio than the experiment where the amount of applied water was greater than 1.2% by weight (Example 9). Thus it is seen that the control of the amount of applied water to not greater than 1.2% by weight will give better results.

In view of the results given in Table 1, it will be readily understood that when the coupled drawing-spinning process is conducted under conditions specified in this invention, it is possible to obtain multifilament yarns of very high tenacity very conveniently under a stable drawing operation hardly accompanied with yarn breakages.

EXAMPLES 10–11 AND COMPARATIVE EXAMPLES 11–13

Granular poly(hexamethylene adipamide) having a number average molecular weight of about 22,000 was melt-spun at a temperature of 290° C. and a spinning rate of 400 m./min., and cooled and solidified. The resulting multifilament yarn was treated with a spinning oil of an aqueous emulsion type and taken up by means of a godet roll. The take-up multifilament yarn (about 5040 denier/205 filaments) was directly forwarded to a drawing device comprising feed rolls and drawing rolls and drawn by one stage drawing without being wound up onto a spool or the like before the drawing. As a result a poly(hexamethylene adipamide) multifilament yarn oriented by the one-stage drawing according to the coupled spinning-drawing process was manufactured.

The oilying agent used was the same as the one used in Examples 1–9. The amount of water applied was varied as indicated in Table 2 by controlling the concentration of the oiling agent in the aqueous emulsion and the rotation rate of the oiling roll.

Between the oiling treatment apparatus and the godet roll, air fluid was caused to collide against the running multifilament yarn by employing same fluid false twister as used in Examples 1–9 to attain the interlacing degree indicated in Table 2. The adjustment of the interlacing degree was conducted in the same manner as in Examples 1–9. For comparison an experiment was conducted where the multifilament yarn to be drawn was not at all interlaced.

Prior to the drawing operation, the multfiilament yarn was preheated to 70° C.

The maximum stretch ratio was determined in the same manner as in Examples 1–9 except that the peripheral speed of feed rolls was changed to 400 m./min.

After the maximum stretch ratio had been determined, the multifilament yarn was drawn at a stretch ratio 0.9 times as high as the maximum stretch ratio, and the tenacity and elongation of the drawn multifilament yarn were measured. At this stretch ratio the drawing was conducted smoothly and stably.

Separately, the multifilament yarn was drawn at a stretch ratio of 3.95 to evaluate the drawability of the yarn.

Experimental conditions and results are shown in Table 2.

TABLE 2.—INTERLACING OPERATION

	Amount of applied water (wt. percent)	Fluid pressure (kg./cm.²)	Yarn tension (g./d.)	Interlacing degree (per meter)	Maximum stretch ratio	Number of yarn breakages at stretch ratio of 3.95 (per kg.) ¹	Tenacity (g./d.)	Elongation (percent)
Comparative Example 11	1.15	0	0.30	0.0	4.05	(²)	5.61	36.2
Example 10	1.15	ca. 3.5	0.30	ca. 0.8	4.69	0.003	7.02	25.1
Comparative Example 12	1.15	ca. 5.5	0.15	ca. 3.5	4.12	0.670	5.80	33.4
Comparative Example 13	1.53	0	0.35	0.0	3.83		5.01	42.1
Example 11	1.53	ca. 3.0	0.35	ca. 0.6	4.29	0.041	6.25	29.3

¹ When the number of yarn breakages per kg. of the yarn is less than 0.07, it may be said that the drawability is good.

² Drawing impossible—Since the stretch ratio of 3.95 was very close to the maximum stretch ratio, yarn breakages occurred very frequently and it was impossible to conduct the drawing operation in the stable state.

As is seen from the results shown in Table 2, when the method of this invention is applied to multifilaments of poly(hexamethylene adipamide), the coupled spinning-drawing process can be accomplished as smoothly and advantageously as in the case of poly-ϵ-caproamide multifilament yarns (Examples 1–9) and the maximum stretch ratio can be greatly increased.

EXAMPLES 12–15 AND COMPARATIVE EXAMPLES 14–21

Granular polyethylene terephthalate having a number average molecular weight of about 30,000 was melt-spun at a temperature of 295° C. and a spinning rate of 350 m./min., and cooled and solidified. The so spun multifilament yarn was treated with a spinning oil and taken up by means of a godet roll. The taken-up multifilament yarn (about 2650 denier/96 filaments) was directly forwarded to a drawing device comprising feed rolls and drawing rolls without being wound up onto a spool or the like, and drawn by the one-stage drawing procedure. As a result an oriented polyethylene terephthalate multifilament yarn was obtained.

As the oiling agent a mixture composed of 85 parts by weight of a fatty acid ester of polypropylene glycol (polyglycol derivative) and 15 parts by weight of polyoxyethylene lauryl ether (nonionic surfactant) was used. The oiling agent was used as it was or after it had been dispersed in trichloroethylene or water, so that the amount of applied water was varied as indicated in Table 3.

Between the oiling treatment device and the godet roll, air fluid was caused to collide against the running multifilament yarn so as to interlace the yarn at an interlacing degree indicated in Table 3. The interlacing degree was controlled by adjusting the pressure of air fluid projected to the yarn passage and the tension of the multifilament yarn passing through the yarn passage of the fluid false twister.

For comparison, an experiment was conducted where the multifilament yarn to be supplied to the drawing device was not at all interlaced.

The maximum stretch ratio of the multifilament yarn was determined in the same manner as in Examples 1–9, and the multifilament yarn was drawn at a stretch ratio 0.9 time as high as the maximum stretch ratio, and the tenacity and elongation of the drawn multifilament yarn were measured. At this stretch ratio the drawing could be conducted smoothly and stably.

Separately, the multifilament yarn was drawn at a stretch ratio of 5.0 to evaluate the drawability of the multifilament yarn.

Experimental conditions and results are shown in Table 3.

a multifilament yarn having a higher tenacity can be obtained under stable drawing operation.

It is also seen that when the interlacing degree is within the range of 0.1–2.0 specified in this invention (Examples 12–15), the amount of applied water not exceeding 1.2% by weight (Examples 12–14) gives a higher maximum stretch ratio than the amount of applied water exceeding 1.2% by weight (Example 15), and thus such lower amount of applied water makes it possible to conduct the coupled spinning-drawing process advantageously with good results.

EXAMPLES 16–17 AND COMPARATIVE EXAMPLES 22–25

Polyethylene-2,6-naphthalate having an intrinsic viscisity of 0.65 calculated based on the measurement conducted at 35° C. in a mixed solvent of phenol: o-dichlorobenzene of a mixing ratio of 6:4, was melt-spun at a temperature of 315° C. and a spinning rate of 350 m./min., and cooled and solidified. The resulting spun multifilament yarn was treated with an oiling agent of an aqueous emulsion type, and taken up by means of a godet roll. The taken-up multifilament yarn (about 2750 denier/125 filaments) was directly forwarded to a drawing device comprising feed rolls and drawing rolls without being wound up onto a spool or the like, and drawn by the one-stage drawing method. As a result an oriented polyethylene-2,6-naphthalate multifilament yarn was obtained.

As the oiling agent a mixture composed of 70 parts by weight of polyoxyethylene stearate (higher fatty acid ester) and 30 parts by weight of polyoxyethylene oleyl ether (nonionic surfactant) was used. The amount of applied water was varied as indicated in Table 4 by adjusting the concentration of the oiling agent in the aqueous emulsion and the rotation rate of the oiling roll.

Between the oiling treatment apparatus and the godet roll, air fluid was caused to collide against the running multifilament yarn by employing the same fluid false twister as used in Examples 1–9 so as to impart the interlacing degree indicated in Table 4 to the multifilament yarn. The adjustment of the interlacing degree was accomplished in the same manner as in Examples 1–9. For comparison, an experiment was conducted where the multifilament yarn was not interlaced at all.

Prior to the drawing operation, the multifilament yarn was preheated at 130° C.

The maximum stretch ratio was determined in the same

TABLE 3.—INTERLACING OPERATION

	Dispersion medium for oiling agent	Amount of applied water (wt. percent)	Fluid pressure (kg./cm.²)	Yarn tension (g./d.)	Interlacing degree (per meter)	Maximum stretch ratio	Number of yarn breakages at stretch ratio of 5.0 (per kg.)[1]	Tenacity (g./d.)	Elongation (percent)
Comparative Example 14	Trichloroethylene	0	0	0.30	0.0	5.36	0.095	5.42	20.1
Example 12	do	0	ca. 3.5	0.30	ca. 0.7	5.87	0.003	6.52	16.5
Comparative Example 15	do	0	ca. 5.5	0.15	ca. 3.0	5.42	0.075	5.61	18.9
Comparative Example 16	Water	0.35	0	0.35	0.0	5.29	0.195	5.21	21.3
Example 13	do	0.35	ca. 3.5	0.35	ca. 0.8	5.82	0.005	6.49	16.8
Comparative Example 17	do	0.35	ca. 5.5	0.10	ca. 3.5	5.32	0.124	5.34	19.5
Comparative Example 18	do	1.10	0	0.25	0.0	5.22	0.427	5.04	21.5
Example 14	do	1.10	ca. 3.5	0.25	ca. 0.9	5.71	0.013	6.22	17.3
Comparative Example 19	do	1.10	ca. 5.5	0.10	ca. 3.5	5.28	0.230	5.19	22.0
Comparative Example 20	do	1.63	0	0.35	0.0	5.09	(2)	4.25	36.1
Example 15	do	1.63	ca. 3.5	0.35	ca. 0.8	5.54	0.042	5.89	17.8
Comparative Example 21	do	1.63	ca. 5.5	0.15	ca. 3.0	5.20	0.580	5.05	22.5

[1] When the number of yarn breakages per kg. of the yarn is less than 0.07, it may be said that the drawability of the yarn is good.

[2] Drawing impossible.—Since the stretch ratio 5.0 was very close to the maximum stretch ratio, yarn breakages occurred very frequently, and it was impossible to conduct the drawing operation in the stable state.

As is seen from the results shown in Table 3, when the interlacing degree of the multifilament yarn to be drawn is within a range specified in this invention, namely 0.1–2.0 (Examples 12–15), a higher maximum stretch ratio can be attained than in the case of the mutifilament yarn failing to meet the interlacing degree requirement of this invention (Comparative Examples 14–21). Accordingly, in this invention a stretch ratio 0.9 times as high as the maximum stretch ratio is also higher, and therefore,

manner as in Examples 1–9, and the multifilament yarn was drawn at a stretch ratio 0.9 times as high as the so determined maximum ratio. At this stretch ratio the drawing could be conducted smoothly and stably. The tenacity and elongation of the so drawn multifilament yarn was measured.

Separately, the multifilament yarn from the fluid false twister was drawn at a stretch ratio of 5.8 to evaluate the drawability. Experimental conditions and results are shown in Table 4.

TABLE 4.—INTERLACING OPERATION

	Amount of applied water (wt. percent)	Fluid pressure (kg./cm.^{2})	Yarn tension (g./d.)	Interlacing degree (per meter)	Maximum stretch ratio	Number of yarn breakages at stretch ratio of 3.95 (per kg.) [1]	Tenacity (g./d.)	Elongation (percent)
Comparative Example 22	1.10	0	0.35	0.0	6.12	0.095	6.24	1.4
Example 16	1.01	ca. 3.5	0.35	ca. 0.6	6.69	0.011	7.71	7.5
Comparative Example 23	1.10	ca. 5.5	0.15	ca. 3.0	6.21	0.076	6.50	9.1
Comparative Example 24	1.56	0	0.30	0.0	5.99	(2)	5.91	14.8
Example 17	1.56	ca. 3.5	0.30	ca. 0.7	6.44	0.041	7.11	8.4
Comparative Example 25	1.56	ca. 5.5	0.10	ca. 3.5	6.01	0.550	6.02	14.6

[1] When the number of yarn breakages per kg. of the yarn is less than 0.07, it may be said that the drawability of the yarn is good.
[2] Drawing impossible—Since the stretch ratio of 5.8 was very close to the maximum stretch ratio, yarn breakages occurred very frequently, and it was impossible to conduct the drawing operation in the stable state.

As is seen from the results shown in Table 4, when the method of this invention is applied to the preparation of polyethylene-2,6-naphthalate multifilament yarns of poly-ε-captoamide, poly(hexamethylene adipamide) and polyethylene terephthalate, a multifilament of a high tenacity can be obtained by the coupled drawing-spinning process under stable drawing operation accompanied hardly with occurrence of yarn breakages.

What we claim is:

1. A method of preparing oriented synthetic continuous multifilament yarns by the coupled spinning-drawing process, which comprises interlacing a bundle of as-spun synthetic continuous multifilaments so that an interlacing degree of 0.1–2.0 per meter of the bundle length is attained, and subsequently drawing the interlaced bundle at a stretch ratio exceeding 4.2, but less than the maximum stretch ratio.

2. The method of claim **1**, wherein the interlacing is accomplished by subjecting the continuous multifilament bundle to the action of a swirling stream of fluid by employing a fluid false twister.

3. The method of claim **1**, wherein the interlacing is conducted so that the interlacing degree is from 0.3 to 1.0 per meter of the length of the continuous multifilament bundle.

4. The method of claim **1** wherein prior to the interlacing treatment the continuous multifilament bundle is subjected to the oiling treatment so that the amount of water applied to the bundle is not greater than 1.2% by weight based on the bundle weight.

5. The method of claim **1**, wherein the continuous multifilament is composed of poly-ethylene terephthalate or a copolyester in which at least 80 mole percent of the recurring units are ethylene terephthalate units.

6. The method of claim **1**, wherein the continuous multifilament is composed of poly-ethylene-2,6-naphthalate or a copolyester in which at least 80 mole percent of the recurring units are ethylene-2,6-naphthalate units.

7. The method of claim **1**, wherein the continuous multifilament is composed of poly-ε-caproamide, polyhexamethylene adipamide or a copolyamide in which at least 80 mol percent of the recurring units are ε-caproamide or hexamethylene adipamide units.

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JAY H. WOO, Primary Examiner

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