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PROCESS FOR PRODUCING BULKABLE FILAMENTARY POLYAMIDE YARNS

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This invention relates generally to the production of filamentary nylon yarn and, more particularly, to an improved process for preparing continuous filament yarns having the property of becoming bulky upon appropriate heat treatment.

It is well known that yarns from staple fibers, particularly from natural fibers such as cotton and wool, are more voluminous or bulky in character than are continuous filament yarns and that such bulkiness leads to fabrics which have high covering power and a soft hand. Various bulking procedures have been attempted in the continuing effort to combine the desirable aesthetic properties of fabrics prepared from staple yarn with the advantages of continuous filament yarn, such as strength and ease of processing.

It is also known that bulky continuous filament yarns have been prepared from filaments which shrink differentially upon treatment with water or heat. One process which has been employed to accomplish differential shrinkage is to extrude filaments of different deniers from the same spinneret. As disclosed in U.S. 2,980,492, polyester filaments of different denier shrink to a considerably different extent when heated and a desirably bulky yarn is produced. However, when the patented procedure is applied to polyamide yarn, very little difference in shrinkage is observed.

It is accordingly the most important object of this invention to provide a process for producing bulkable, filamentary, polyamide yarns. Another objective is to provide a process for producing a continuous filament polyamide yarn containing filaments of the same composition but different deniers, the higher denier filaments having the capability of shrinking to a significantly greater extent than the lower denier filaments.

The above objects are accomplished by extruding and quenching a plurality of low and relatively high denier polyamide filaments, arranging the quenched filaments to avoid contact between low and high denier filaments and gathering the filaments, after an axial advance from the point of arrangement through a distance sufficient to develop substantially maximum undrawn orientation, into a yarn bundle adapted to be drawn. Preferably, the drawing step is carried out in free space, with no frictional contact between the yarn and solid surfaces, while simultaneously heating the yarn end in the draw zone with a jet of steam. Alternately, the yarn end may be pin drawn in the conventional manner and subsequently heated with steam in a controlled relaxation step. To insure sufficient shrinkage differential, the average drawn denier of the low denier filaments should be no greater than 2 and the average drawn denier of the relatively high denier filaments should be at least 1.5 times that of the low denier filaments. If the undrawn yarn is packaged before drawing, the filaments should

first be conditioned in a high humidity (preferably steam) atmosphere to insure good package formation. For convenience, this conditioning step has been accomplished as the filaments advance from the guide at which they were converged and arranged. If the undrawn yarn is not packaged but advanced directly to a draw zone, steam conditioning may be omitted.

The above sequence of process steps produces a yarn which, on appropriate heating, e.g., in boiling water, develops a desirable bulkiness due to the higher denier filaments shrinking to a considerably greater extent than the lower denier filaments. The bulkable yarn also has the advantage that there is no difference in retraction between the filaments when the drawn yarn is removed from the package for processing into fabric, i.e., it exhibits no troublesome loops of the type which interfere with such processing.

The shrinkage differentials disclosed herein are believed to arise from a higher degree of molecular orientation obtained when the filaments are separated according to denier during the period when most of the undrawn filament orientation occurs, i.e., after the filaments are properly arranged by passage in contact with a guide. Conventionally, undrawn polyamide filaments are brought in gliding contact after quenching with a solid surface such as a guide of the type normally used for converging the filaments into a single yarn end. If this is not done, substantially all of the attenuation of the filament takes place near the spinneret where the filament is quite plastic and little orientation occurs. As disclosed more fully hereinafter, the difference in orientation between the low and relatively high denier filaments is insufficient to produce the desired differential shrinkability if the filaments are combined or gathered into a single bundle at the point of convergence. Although avoidance of contact between low and high deniers during attenuation is a requisite in the instant process, the filaments must be combined into a single yarn end in advance of the draw zone in order to obtain satisfactory drawing performance for all of the filaments.

In the following examples, the degree of orientation is determined by birefringence measurements which involve observation of the undrawn filaments between crossed plane-polarizing elements (e.g., Nicol prisms) using a Soleil compensator for accuracy. This method is treated in detail by Heyn in Textile Research Journal, 22, 513 (1952).

EXAMPLE I

Polyhexamethylene adipamide having a relative viscosity of 33.5 is prepared and extruded in the conventional manner using apparatus of the type disclosed in U.S. 2,217,743 except that the spinneret has 34 holes varying in size as listed in Table I–A. The filaments are quenched by passing air transversely across a chimney through which they travel. After quenching, the fourteen low denier filaments and the remaining twenty filaments are converged into separate bundles by passing them separately at a slight angle over matte finish, ceramic coated pins and then over a second pin disposed at right angles to the first pins. The two separate bundles are passed through a steam treatment enclosure provided with entry and exit openings, steam inlets and a condensate outlet. Steam is supplied to the enclosure at 5 p.s.i.g. and

the yarn is exposed to these turbulent conditions for a distance of 72 inches. The two filament bundles are then gathered into a single yarn end which is packaged at a speed of 1560 yards/min. Subsequently, the yarn is unwound and drawn to a machine draw ratio of 3.2 by passing it around spaced rolls, the second of which has a higher peripheral speed. Between these feed and draw rolls, the yarn is passed through an enclosure within which steam at 20 p.s.i.g. and 275° C. is jetted on the yarn in an intersecting relationship. After drawing, the yarn is wound into a package in a conventional manner. When exposed to boiling water, the cover and hand of the fabric are greatly improved due to the difference in shrinkage between the low and higher denier filaments in the yarn.

For purposes of comparison, samples of the packaged, undrawn filaments are taken for birefringence measurements. The results of these tests are shown in Table I–A below. In additional tests, it is observed that over 75% of the undrawn orientation, as indicated by birefringence measurements, occurs after the quenched filaments pass over the convergence guide pins but within about 36 inches thereof. Beyond this point there is little change in orientation until the filaments are drawn.

Drawn yarn is separated into several bundles according to denier to facilitate the shrinkage determinations reported in the following table. It should be noted that the residual shrinkage in the one denier filaments is less than 70% of the average residual shrinkage in the remaining filaments.

Table I–A

Spinneret			Filaments		
Number holes	Diam., in.	Length, in.	Birefringence	Denier	Percent shrinkage
14	0.009	0.012	0.0262	1.0	5.25
6	0.012	0.014	0.0148	2.7	7.92
5	0.014	0.016	0.0163	3.1	7.50
5	0.016	0.018	0.0134	3.6	8.28
4	0.018	0.020	0.0141	3.9	7.92

Table I–B shows results obtained when the ratio of low to high denier filaments is varied. For comparison, the results obtained with a yarn having 34 filaments of two denier each is included. Taffeta fabrics are prepared from these yarns in the normal fashion, finished under relatively relaxed conditions and rated for dry, bulky hand, the best fabric being given a rating of one.

Table I–B

Number of 1 denier filaments	Number of 2–4 denier filaments	Rating
20	14	1
14	20	2
9	26	3
(1)	34	4

[1] Control, uniform d.p.f.

EXAMPLE II

Filamentary yarn was prepared as in Example I except that it was cold drawn over pins in the conventional manner and then steamed while permitting 9% relaxation, following the controlled relaxation procedure described in U.S. 3,003,222. Table II shows shrinkages and undrawn filament birefringence values obtained when the quenched high and low denier filaments were converged separately as in Example I before steam conditioning. Also shown in Table II, for comparison, are shrinkages and birefringence values obtained when the quenched high and low denier filaments were converged into a single yarn end before conditioning. It should be noted that the residual shrinkage in the lowest drawn denier filaments is less than 85% of the average residual shrinkage in the remaining filaments when converged into two separate bundles but approaches 100% when converged as a single bundle. As in Example I, it is found that birefringence of the undrawn filaments reaches a maximum within about 36 inches after passing over the convergence guides.

Table II

Filaments combined before steam conditioning			Filaments separated during steam conditioning		
Birefringence	Denier	Shrinkage, percent	Birefringence	Denier	Shrinkage, percent
0.0185	1.0	7.0	0.0254	1.1	6.0
0.0157	2.6	7.2	0.0138	2.5	7.2
0.0165	3.1	7.1	0.0133	3.1	7.2
0.0152	3.7	7.3	0.0144	3.5	7.2
0.0147	4.0	7.3	0.0129	4.0	7.5

The above examples illustrate the advantages of the instant process in which differential denier filaments are extruded from different holes of the same spinneret, quenched, separated according to denier in their passage over a guide, attenuated, gathered and subsequently drawn to produce a non-loop filamentary yarn which is easily processed into fabric but which shrinks differentially when the fabric is heated, as in conventional fabric finishing operations, to produce a fabric with improved cover and hand. The differences in filament shrinkage obtained by this process are not so high as to produce a highly bulked yarn or fabrics having a cotton-like hand, but are sufficient to bring the lower denier filaments to the surface of the fabric, thus producing a moderate increase in bulkiness and a soft luxurious hand which is highly desirable.

As illustrated in the tables accompanying the examples, a particular combination of process steps must be utilized to attain the desired results. The denier of the lower denier filaments should not be above about 2, preferably not above 1.5, since the differences in shrinkage attained with variation in denier are greatest in the lower denier range. In addition, the presence of such low denier filaments in the surface of the fabric produces a soft hand. If desired, the low denier filaments may vary in denier but their average denier should not be greater than 2. Likewise, the higher denier filaments may vary in denier, as exemplified, but their average denier should be at least 1.5 times and preferably at least twice that of the lower denier filaments in order to insure the desired shrinkage differential.

While, as shown in Table I–B, a minor proportion of the lower denier filaments will effect a substantial improvement in fabric aesthetics, it is desirable that the lower denier filaments comprise a major numerical proportion of the yarn.

The quenched, differential denier filaments must not be converged into a single filament bundle at the usual point of convergence since, surprisingly, this results in a considerable loss in the shrinkage potential of the low denier filaments, as best illustrated in Table II. To obtain the desired shrinkage differential, the filaments must be separated according to denier for a sufficient distance after passing in contact with the guide to facilitate development of substantially maximum undrawn orientation. This is accomplished if the filaments are kept separated until the birefringence has substantially reached the maximum value for the undrawn filaments. Usually this will be accomplished in a distance of 36 inches or less if a high humidity conditioning step is employed. If this step is omitted, a somewhat greater distance may be required. The axial advance from the point of convergence and separation may also vary to some extent depending on filament denier, spinning speed and other

process variables. Separation may be accomplished by guiding the filaments into two or more bundles according to denier or, if convenient, the filaments may be spread apart over a guide as a ribbon to avoid contact between low and relatively high denier filaments. The latter must be combined into one bundle before drawing, otherwise the drawing performance of the lower denier filaments is not satisfactory. After the attenuated filaments have been gathered, the resulting single yarn end may be passed directly to the drawing stage or may be wound into a package and drawn subsequently.

The drawing step is preferably carried out in free space, i.e., with no frictional contact between the yarn and solid surfaces. As is apparent from a comparison of Tables I–A and II, such space drawing provides the greatest shrinkage difference between the high and low denier filaments and accordingly is the preferred procedure. Alternately, the gathered filamentary yarn may be cold drawn over one or more pins, as in Example II, and then subjected to steam treatment with controlled relaxation as described and claimed in U.S. 3,003,222. The steam treatment with relaxation is necessary with pin drawn yarns to avoid loopiness due to differences in the room temperature retraction of the filaments when the drawn yarn is unwound from its package.

The preferred polyamides for use in the process of this invention are poly(hexamethylene adipamide) and poly(epsilon caproamide). Other suitable polyamides include those described in U.S. Patents 2,071,253; 2,130,523 and 2,130,948.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. In the production of yarn, the steps of: guiding freshly spun, axially advancing, differential denier, polyamide filaments into bundles according to denier; and gathering said bundles, after their axial advance under tension through a distance sufficient to develop substantially maximum undrawn orientation, into a single yarn end adapted to be drawn to a denier of less than 2 for the filaments from one of said bundles and a denier at least 1.5 times as great for the remaining filaments.

2. In the production of yarn, the steps of: guiding freshly spun, axially advancing, differential denier, polyamide filaments into separate bundles according to denier; gathering said separate bundles, after their axial advance under tension through a distance sufficient to develop substantially maximum undrawn orientation, into a single yarn end; and drawing said yarn end, the filaments from one of said bundles having a drawn denier of less than 2, the remaining filaments having a drawn denier at least 1.5 times as great.

3. In the production of yarn, the steps of: spinning low and relatively high denier filaments from a molten polyamide; quenching the spun filaments; separating the quenched filaments, by passage in contact with guide means, into bundles according to denier; conditioning said bundles by exposure to an atmosphere having a relative humidity of at least 90% and a temperature of at least 65° C.; and gathering said bundles, after their axial

advance under tension through said atmosphere and through a further distance sufficient to develop substantially maximum undrawn orientation, into a single yarn end adapted to be drawn to a denier of less than 2 for the filaments from one of said bundles and a denier at least 1.5 times as great for the remaining filaments.

4. A process including the steps of spinning, quenching and drawing differential denier nylon yarn containing a major numerical proportion of filaments having a drawn denier of less than 1.5, the improvement of which comprises guiding the quenched filaments into low and relatively high denier bundles and, in advance of said drawing step but after their axial advance under tension through a distance sufficient to develop substantially maximum undrawn orientation, gathering the bundles into a single yarn end.

5. The process of claim 4 wherein said yarn end is cold drawn by snubbing contact with an element situated in the yarn path of travel between spaced feed and draw rolls and subsequently relaxed in a steam atmosphere.

6. In the production of yarn, the steps of: spinning low and relatively high denier polyamide filaments; arranging the axially advancing filaments to avoid contact between low and high denier filaments; and gathering the filaments, after an axial advance from the point of arrangement through a distance sufficient to develop substantially maximum undrawn orientation, into a bundle adapted to be drawn to a denier of less than 2 for the low denier filaments and a denier at least 1.5 times as great for the remaining filaments.

7. A process including the steps of spinning, quenching and drawing differential denier nylon yarn containing a major numerical proportion of filaments having a drawn denier of less than 1.5, the improvement of which comprises arranging the quenched filaments to avoid contact between those in said major porportion and those remaining and gathering the arranged filaments, in advance of said drawing step but after an axial travel from the point of arrangement through a distance sufficient to develop substantially maximum undrawn orientation, into a single yarn end.

8. In the production of yarn, the steps of: guiding as-spun, axially advancing, differential denier, nylon filaments to avoid contact between low and relatively high denier filaments; gathering the filaments, after a guided advance through a distance sufficient to develop maximum undrawn orientation, into a single yarn end; and drawing said yarn end.

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