

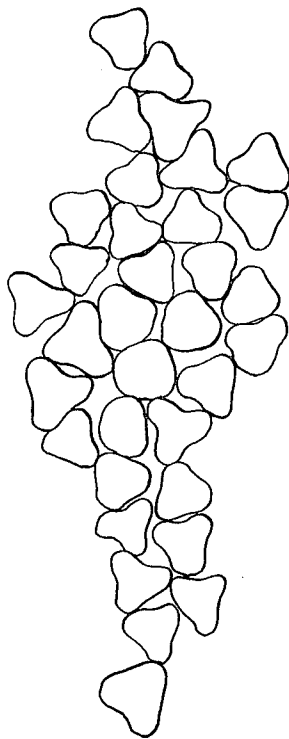
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TRILOBAL FILAMENTARY YARNS

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TRILOBAL FILAMENTARY YARNS

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This application is a continuation-in-part of application Serial No. 267,310, filed March 22, 1963, which in turn is a continuation-in-part of the earlier application Serial No. 193,869, filed May 10, 1962, and now abandoned.

This invention relates to improved synthetic yarns comprising trilobal filaments.

Yarns produced from synthetic polymers in which the filaments are of trigonal cross section having been found to offer substantial improvements with respect to luster, covering power and resistance to soiling if the cross-sectional shape conforms to certain parameters as set forth in U.S. Patents 2,939,201 and 2,939,202, and discussed in greater detail hereinafter.

The said cross-sectional shapes include concavely trilobal sections (as in FIGS. 1 and 2 of Patent 2,939,201) and also triangular cushion shapes as in FIG. 1 of said Patent 2,939,202. All these shapes could be aptly embraced by the term "trigonal," in the sense that they are all three cornered shapes. However, the practical art appears to have adopted the term "trilobal" as a generic term for the various fiber shapes included in the above two patents. Accordingly, this term will be adhered to throughout this specification and claims, and is to be understood in the above indicated generic sense. For the same reason, the expression "high-luster, trilobal filaments" as used herein shall be understood as referring to filaments of the types described in U.S. Patents 2,939,201 and 2,939,202. These trilobal filaments are characterized by tip radius ratio, modification ratio, and arm angle, all of these parameters being described in detail in the above patents.

It has been found that trilobal filament yarns of this type are generally very attractive when woven into fabrics suitable for women's apparel, such as dresses and blouses. However, certain difficulties have been encountered in producing completely satisfactory fabric for this market. The difficulty is due to the fact that the high sparkle and luster of the yarn (one of its most desirable features) accentuates streaks and quill junctions caused by small, unavoidable variations, in yarn properties arising from slight variations in tension, denier, filament cross section, etc. in the production of the yarn. These variations bring about a marked variation in yarn luster so that different packages of yarn may vary considerably in luster, or relatively abrupt changes in luster may occur within a package. It is almost impossible to control the yarn preparation in a commercial process within sufficiently narrow limits to prevent these highly undesirable non-uniformities in the fabric.

Process variations of this magnitude do not cause appreciable non-uniformity in fabric prepared from non-lustrous yarns such as conventional, round cross-section yarn.

It is an object of this invention to provide a high-luster, trilobal filament yarn of improved uniformity with respect to luster. Another object is to provide packages of trilobal yarn which may be used to produce fabrics that are greatly improved with respect to streaks and quill junctions. Other objects will become apparent from the examples and discussion which follow.

The above objects are accomplished by a yarn comprising a plurality of trilobal synthetic polymer filaments

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of high luster, the modification ratio of the various filaments differing in a reasonably uniform fashion over an appreciable range, as more particularly set forth below, said variation in modification ratio persisting throughout substantially the entire length of yarn in a given yarn package.

The modification ratio is conveniently determined by circumscribing a circle about the tips of the three substantially equispaced lobes of a trilobal filament cross section and then inscribing a circle within the cross section. The ratio of the radius of the circumscribed circle to the radius of the inscribed circle, both having approximately the same center, is the modification ratio. A filament having a round cross section has a modification ratio of 1.0. Accordingly, all trilobal cross sections have modification ratios greater than 1.0.

Among the trilobal filaments of U.S. Patent 2,939,201, the greatest problem with respect to streakiness is encountered with those having a modification ratio within the range from about 1.4 to about 2.5 and, consequently, the present invention is of greatest value in this area.

Now, according to this invention, the individual filaments of which the yarn is made are selected from different groups or species (or directly manufactured in different groups or species), each species differing from the other as to modification ratio. For instance, in a preferred embodiment, the continuous filament yarns of this invention are comprised of at least four species of trilobal filaments, with the filaments of each species having a substantially constant modification ratio along their lengths. The species containing the largest number of filaments should constitute not more than about 45% of the total number of filaments in the yarn, and none of the other species should contain more than 35% of the remaining filaments.

The magnitude of the range and the distribution of the filaments with respect to modification ratio within this range are characterized by (1) a standard deviation (s) of at least 0.08 (preferably at least 0.10), (2) a skewness coefficient (a_3) within the range of -0.7 to $+0.7$, and (3) a kurtosis coefficient (a_4) not exceeding 4.0, and preferably between 1.0 and 4.0.

The parameters s , a_3 and a_4 , which characterize the distribution of the filaments in the yarn with respect to modification ratio may be calculated, when the ratios of all the filaments in the yarn are known, from the following equations:

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

$$a_3 = \frac{\sum (x - \bar{x})^3}{ns^3}$$

$$a_4 = \frac{\sum (x - \bar{x})^4}{ns^4}$$

where x is the individual filament modification ratio, n is the number of filaments in the yarn, and $\bar{x}$ is the mean modification ratio $\Sigma x/n$.

The above parameters may be used to plot a Gram-Charlier type A distribution curve. The general form of the equation representing this type of distribution is:

$$P_z = \frac{1}{\sqrt{2\pi}} (e^{-z^2/2}) \left[1 - \frac{a_3}{6} (3z - z^3) + \frac{a_4 - 3}{24} (3 - 6z^2 + z^4) \right]$$

where

$$z = \frac{x - \bar{x}}{s}$$

The equation

$$P_z = \frac{1}{\sqrt{2\pi}} (e^{-z^2/2})$$

will be recognized as the equation of the normal distribution of the normal distribution or normal probability curve where P_z is the probability or frequency of occurrence of a deviation of magnitude z in a large number of observations. The material within the brackets represents the corrections for skewness and kurtosis. Skewness and kurtosis are measures of the shape of the distribution. Skewness refers to the lack of symmetry and kurtosis measures an excess or deficiency of values in the tails of a distribution. For a symmetrical (normal) distribution the skewness coefficient (a_3) is 0. Distributions which are unsymmetrical because of an excessive number of high values have a positive skewness, while those which are unsymmetrical because of a preponderance of low values have negative skewness. For a symmetrical or normal distribution the kurtosis coefficient (a_4) is 3. When this coefficient is less than 3 the distribution has shorter tails and squarer shoulders, i.e., has a flatter distribution than the normal distribution and is said to be platykurtic. When the kurtosis coefficient is greater than 3, the distribution has long tails and is more sharply peaked than the normal distribution and is said to be leptokurtic.

Preferably, the yarn of this invention is prepared by extruding molten polymer through a spinneret having a plurality of Y-shaped orifices, as described in U.S. Patent 2,945,739, or triangular orifices as described in U.S. Patent 2,939,202, the spinneret having superimposed thereon a metering plate having a plurality of orifices, each of which communicates directly with one of the spinneret orifices as described in the copending application of James S. Cobb, Serial No. 208,748, filed July 10, 1962, issued July 2, 1963, as U.S. Patent No. 3,095,607. The extrusion orifices of the spinneret shown in the Cobb application may be replaced by Y-shaped or triangular orifices varying in shape so that filaments of varying modification ratio are produced. The orifices in the metering plate are of uniform size so that a constant volume of polymer is delivered to each spinneret orifice. If it is desired to vary the denier of the filament, the holes in the metering plate may be varied in size or, in some instances, it may be satisfactory to omit the metering plate.

The term "quill junction" refers to that point in a fabric where, during its preparation, the yarn package, i.e., the quill, in the shuttle is exhausted and is replaced by a new package. If the yarns on the old and new packages differ sufficiently in appearance, e.g., in luster, the junction becomes visible, while, if there is no difference in the yarns, the junction is not apparent.

The sole figure in the accompanying drawing represents a photomicrographic view of the cross-section of a typical 34-filament yarn produced according to this invention.

The following examples further illustrate this invention.

EXAMPLE I

Poly(hexamethylene) adipamide was prepared in the conventional manner. The polymer was melt extruded to form trilobal filaments having a relative viscosity of 40 as described in U.S. 2,939,201, except that a metering plate having round orifices was superimposed on the spinneret, as previously described, to supply equal volumes of polymer to the various spinneret orifices, and the shape of the spinneret orifices were varied to give various modification ratios as shown in Table 1 below. The filaments were quenched by passing air transversely across them in the conventional manner. The yarn was drawn at a ratio of 2.62 and given a hot relaxation treatment as described in U.S. 3,003,222, the yarn being permitted to retract 9%. The denier of the drawn yarn was 70. The

number of filaments of each modification ratio and the corresponding modification ratios are shown in Table 1, but the total in each yarn was 34.

Yarns A and B with varying modification ratios were spun in this manner. The tip radius ratios and the arm angles for the various filaments are also shown in Table 1. For comparison, yarn C, a 70-denier, 34-filament yarn was spun as above, except that the modification ratio was held substantially constant. The tip radius ratio of yarn C was 0.38, and the arm angle was 44°. The standard deviations (s) and the coefficients a_3 and a_4 are given in Table 2. Yarns A, B, and C were woven into 104 x 76 taffeta fabric and the fabric was examined for streakiness and luster level. The fabrics were rated in order of their streakiness and luster and the ratings are given in Table 2 below, a rating of 1 being best for streakiness while a rating above 3 indicates unacceptable streakiness. The luster rating is based on a scale of 1 to 5, where 1 indicates very low luster and 5 represents a very high luster.

Table 1

Modification Ratio	Tip Radius Ratio	Arm Angle (deg.)	Number of Filaments		
			Yarn A	Yarn B	Yarn C
1.4-----	0.49	63	5	-----	-----
1.5-----	0.44	55	8	-----	-----
1.6-----	0.39	47	11	-----	9
1.7-----	0.36	40	8	1	25
1.8-----	0.34	33	2	12	-----
1.9-----	0.31	28	-----	10	-----
2.0-----	0.30	24	-----	8	-----
2.1-----	0.28	20	-----	2	-----
2.2-----	0.26	16	-----	1	-----
Total-----			34	34	34

Table 2

Fabric	Modification Ratio	s	a_3	a_4	Streakiness	Luster
A-----	1.4-1.8	0.114	0.039	2.07	1.5	5
B-----	1.7-2.2	0.111	0.255	2.84	1.5	4
C-----	1.6-1.7	0.045	0.783	1.71	4.0	5

EXAMPLE II

Yarns D, E, F, G, and H were prepared following the procedure of Example I except that the modification ratios found were as shown in Table 3. The tip radius ratios and the arm angles are also shown in Table 3. The standard deviation values and the coefficients a_3 and a_4 for these yarns are shown in Table 4. Fabrics prepared from these yarns as described in Example I were rated for streakiness with the results shown in Table 4.

Table 3

Modification Ratio	Tip Radius Ratio	Arm Angle (deg.)	Number of Filaments				
			D	E	F	G	H
1.35-----	.52	68	-----	-----	1	-----	-----
1.40-----	.49	63	-----	-----	-----	-----	2
1.45-----	.46	59	-----	4	-----	-----	-----
1.50-----	.44	55	6	5	1	-----	2
1.55-----	.41	51	11	6	3	-----	3
1.60-----	.39	47	13	11	10	3	2
1.65-----	.38	43	4	4	11	5	5
1.70-----	.36	39	-----	4	1	6	4
1.75-----	.35	36	-----	-----	3	3	3
1.80-----	.34	33	-----	-----	4	10	1
1.85-----	.32	30	-----	-----	-----	1	3
1.90-----	.31	28	-----	-----	-----	4	1
1.95-----	.30	26	-----	-----	-----	-----	1
2.00-----	.29	24	-----	-----	-----	2	4
2.05-----	.28	22	-----	-----	-----	-----	1
Total-----			34	34	34	34	34

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Table 4

Yarn	s	a ₃	a ₄	Streakiness
H-----	0.186	0.28	2.19	1.5
G-----	0.104	0.31	2.50	1.5
F-----	0.094	-0.28	4.03	3.2
E-----	0.074	-0.12	2.43	4
D-----	0.042	-0.02	1.33	5

EXAMPLE III

Five different seventy-denier, 34-filament yarns were prepared as described in Example I for yarns A and B, each yarn containing filaments which varied in modification ratio over a range of 0.5, while the computed average modification ratio for the five yarns were, respectively, 1.54, 1.59, 1.72, 1.81 and 1.91. (The standard deviations, skewness coefficients and kurtosis coefficients for these yarns were well within the limits herein above set forth for this invention.)

The several yarns were used as a filling in a commercial trilobal filament yarn warp to determine the limits within which the average modification ratio must be controlled to obtain satisfactory quill junctions and consequently a good fabric appearance. To accomplish this, the fabric containing the 1.54 average modification ratio yarn was compared with each of four fabrics made in the same manner from the other four yarns, and the difference in luster of the fabrics being compared was noted in terms of quill junction rating. The results of these comparisons are shown in Table 5, based on a scale wherein a rating of 1 indicates no visible junction; a rating of 5 indicates an extremely severe junction, and a rating of 3.0 is barely acceptable. The table shows that a difference in average modification ratio of as much as 0.37 can be tolerated with this yarn without giving unacceptable quill junctions.

Table 5

Average Modification Ratio	Difference in Average Modification Ratio	Quill	Junction Rating
1.54 v. 1.59-----	0.05	1.2	Good.
1.54 v. 1.72-----	0.18	2.1	Acceptable.
1.54 v. 1.81-----	0.27	2.5	Do.
1.54 v. 1.91-----	0.37	3.0	Barely acceptable.

Table 6

Average Modification Ratio	Difference in Average Modification Ratio	Quill	Junction Rating
1.60 v. 1.60-----	0.00	1.4	Good.
1.60 v. 1.56-----	0.04	2.3	Acceptable.
1.60 v. 1.53-----	0.07	3.4	Unacceptable.
1.60 v. 1.50-----	0.10	3.4	Do.
1.53 v. 1.69-----	0.16	3.6	Do.
1.55 v. 1.75-----	0.20	4.7	Do.

For comparison, Table 6 shows results obtained when the same test was run with yarns in which the modification ratio of the filaments within a given yarn was held substantially constant. These results indicate that when the modification ratio within each yarn is held essentially constant, the average modification ratio from one yarn package to another must be controlled so that differences of no more than about 0.05 occur, in order to obtain acceptable quill junctions. Further tests, however, have shown that variations of about 0.1 from one yarn package to another normally occur in commercial production of yarns of this type, and control of these variations within the limits required for acceptable quill junction rating is practically impossible.

6 EXAMPLE IV

Polyhexamethylene adipamide (6-6 nylon) flake was prepared in the conventional manner except that a 25% aqueous solution of an antistatic agent, nonyl phenoxy capped polyethylene ether alcohol of about 1,600 molecular weight, was added during polymerization in sufficient amount to provide a concentration of 2.5% by weight of the polymer. In a similar fashion, a copolymer flake containing 2.5% by weight of the antistatic agent was prepared from the mixed salts of hexamethylene diamine and adipic acid, and hexamethylene diamine and isophthalic acid, the latter salt being present in an amount equivalent to 8% by weight of the total salt.

The 6-6 and 66/6-I flakes were melted separately and extruded from alternate rows of holes in the same spinneret to form seven 6-6 filaments and seven 66/6-I filaments. The filaments were extruded to form trilobal filaments as described in Example I except that the spinneret orifices were all of the same size and shape. The viscosities of the 6-6 and 66/6-I polymers differed, however, and this led to a difference in the average modification ratios of the filaments from the two polymers. In addition, a temperature difference of about 3° C. existed between the center and outside of the spinneret assembly and this led to further variations in modification ratio. After extrusion, the filaments were quenched in the conventional manner and converged at a guide to form a yarn. The yarn was then passed twice around a feel roller with its associated separator roller and thence to a draw roller having a higher peripheral speed whereby the yarn was drawn to a ratio of 3.0. The draw roller was located in a heated compartment having an air temperature of 150° C. From the draw roller, the yarn was passed around a second roller in the heated compartment and then back around the draw roller, the second roller having the same peripheral speed as the draw roller so that the yarn was subjected to a constant length heat treatment. The yarn then passed from the heated compartment directly to and around a roller having a lower peripheral speed whereby the yarn was permitted to retract 2.5% in length. The hot relaxed yarn was then passed through an interlacing jet as described by Dahlstrom and Wert in their U.S. Patent Number 3,069,836. The yarn which had a final denier of 40 was then wound into a package in the conventional manner.

Table 7 below gives modification ratios, tip radius ratios and arm angles for the individual filaments of two yarns, I and J, produced as described above. Table 8 gives the standard deviations (s) and the a₃ and a₄ coefficients for these yarns and indicates the appearance of fabrics woven from the yarns. The 6-6 and 66/6-I polymer melt viscosities for yarn I were 900 and 1600 poises respectively and for yarn J were 800 and 1600 poises respectively.

Table 7

Modification Ratio		Tip Radius Ratio		Arm Angle (deg.)	
Yarn I	Yarn J	Yarn I	Yarn J	Yarn I	Yarn J
1.68	1.60	0.36	0.39	42	47
1.76	1.64	0.34	0.38	37	45
1.77	1.64	0.34	0.38	36	45
1.78	1.68	0.33	0.36	35	42
1.78	1.68	0.33	0.36	35	42
1.80	1.71	0.33	0.35	34	40
1.85	1.81	0.32	0.33	31	33
1.97	2.05	0.30	0.28	24	21
2.05	2.05	0.28	0.28	21	21
2.07	2.10	0.28	0.28	20	19
2.11	2.10	0.27	0.28	19	19
2.12	2.10	0.27	0.28	18	19
2.14	2.15	0.27	0.27	18	18
2.21	2.15	0.26	0.27	16	18

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Table 8

Yarn	s	a_3	a_4	Streakiness
I-----	0.18	0.104	1.25	Satisfactory. Barely satisfactory.
J-----	0.22	0.059	1.02	

The foregoing examples illustrate the value of this invention in controlling quill junctions and streaks in fabrics prepared from high-luster trilobal filaments.

I have discussed above the distribution parameters for desirable variations in the modification ratio of filaments within a single yarn in this invention. These parameters were selected with the view of keeping the filaments inside the range of modification ratios within which high-luster yarns are obtained. (See U.S. Patents 2,939,201 and 2,939,202, FIG. 4 each.) Obviously, however, in yarns containing a considerable number of filaments, a few filaments may have cross-sectional shapes falling outside the range normally required for high-luster yarns without unduly affecting the luster of the yarn as a whole. The filament modification ratios should be distributed in a reasonably uniform fashion over the range selected. A badly skewed distribution leads to poor results.

As indicated previously, at least four species of filaments should be present and not more than 45% of the filaments should fall in the predominant species, while not more than 35% of the remaining filaments should be within any one of the remaining species. As illustrated in the examples, more than four species may be present; however, due to the expense in fabricating spinnerets, the number of different species is preferably held to the minimum required to provide the desired result.

This invention is obviously applicable only to multi-filament yarns. While the applicability of the invention will vary depending upon the type of yarn, it is generally useful for high-luster trilobal filament yarns containing ten or more filaments.

It must be appreciated, of course, that yarns which are nominally of uniform filament cross section may exhibit some variation in cross-sectional shape among the filaments in the yarn. This variation is not sufficient to achieve the purpose of this invention, although, for short periods, where control of the process may be poor, a relatively wide spread in modification ratio may be encountered. Such uncontrolled variations, however, aggravate the problem of streakiness in fabrics, as shown in Example III. Surprisingly, this invention, by deliberately imposing a predetermined variation in filament modification ratio within the yarn, achieved a marked improvement in fabric uniformity. Although some uncontrolled variation may still occur and be superimposed on the deliberately imposed variation, such variations have far less effect on fabric uniformity than is the case where an attempt is made to prepare yarn with uniform filament modification ratio. This is illustrated in Tables 5 and 6. It is to be understood, therefore, that this invention is not concerned with the production of relatively short lengths of yarn in which the filament modification ratio varies considerably, but rather contemplates the production of a package or a plurality of packages of high-luster

yarn wherein substantially the entire length of yarn has the required filament modification ratio. The yarn packages referred to may, of course, be small packages such as cones, spools, pirns, and the like, or may be beams of yarn weighing hundreds of pounds.

As many widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that this invention is not to be limited to the specific embodiments thereof except as defined in the appended claims.

What is claimed is:

1. A yarn package of continuous-filament, synthetic, textile yarn, said yarn being composed of a plurality of species of trilobal filaments, the individual filaments within each species being of essentially the same modification ratio, but the species differing from each other in respect to said ratio, the distribution of modification ratios over the entire group of filaments constituting the yarn being such as to give the group

(1) a standard deviation (s) of at least 0.08,

(2) a skewness coefficient (a_3) within the range of -0.7 to $+0.7$,

and

(3) a kurtosis coefficient (a_4) in the range of 1.0 to 4.0.

2. A yarn package as in claim 1, the number of species being at least four.

3. A yarn package as in claim 2, wherein the species containing the largest number of filaments contains not more than 45% of the total number of filaments in the yarn, while none of the remaining species contains more than 35% of the remaining filaments.

4. A yarn package of continuous-filament, synthetic, polyamide, textile yarn, said yarn being composed of a plurality of species of trilobal filaments having modification ratios in the range of 1.4 to 2.5, the individual filaments within each species being of essentially the same modification ratio, but the species differing from each other in respect to said ratio, the distribution of modification ratios over the entire group of filaments constituting the yarn being such as to give the group

(1) a standard deviation (s) of at least 0.1,

(2) a skewness coefficient (a_3) in the range of -0.7 to $+0.7$,

and

(3) a kurtosis coefficient (a_4) in the range of 1.0 to 4.0.

5. Fabric containing yarns as defined in claim 1.

6. Fabric containing polyamide yarns as defined in claim 4.

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MERVIN STEIN, *Primary Examiner*.