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Continuation-in-part of application Ser. No. 671,751, Sept. 29, 1967, now abandoned.

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[54] **HEAT-SET MECHANICALLY CRIMPED FILAMENTS HAVING DIFFERENT POLYAMIDE COMPOSITIONS**

6 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **57/140,** 28/72.12, 28/72.14, 57/157, 161/173, 260/78, 260/857

[51] **Int. Cl.** **D02q 3/04,** D02g 1/02, D02g 1/12

[50] **Field of Search** 28/72, 72.17, 72.14, 72.12; 57/140, 157; 161/173; 260/78, 857

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ABSTRACT: A bulky yarn may be prepared by mechanically crimping yarns of intermingled continuous filaments having at least two different compositions. Typically one of the compositions is a polyamide derived from bis (para-aminocyclohexyl) methane and dodecanedioic acid, and another of the compositions is a copolymer derived from bis (para-aminocyclohexyl) methane and a mixture of dodecanedioic acid and isophthalic acid. In the typical mixed yarn the copolymer contains about 70 percent trans-trans stereoisomer in the diamine. The mixed yarn has about 2 to 25 percent elongation available due to crimp (crimp index). The two types of crimped filaments in the yarn have a difference in filament length (DFL) of at least 5 percent, this DFL being greater than the DFL of filaments prior to crimping.

FIG. 1

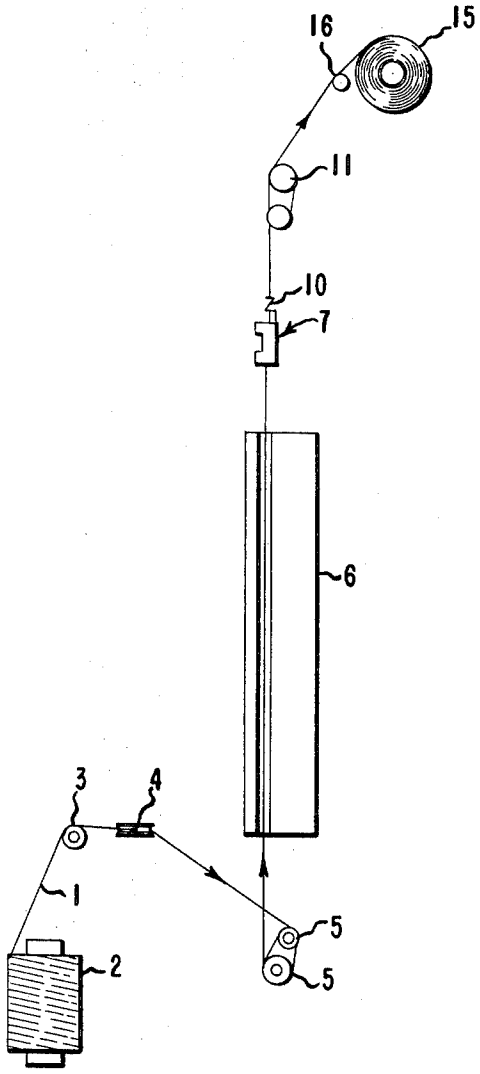


FIG. 2

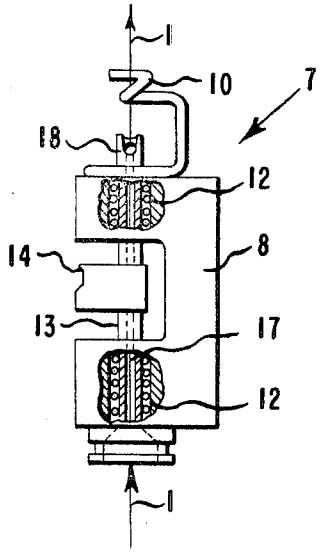


FIG. 3

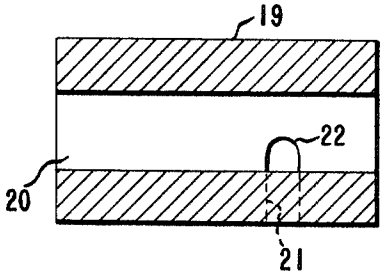
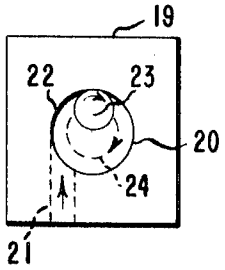


FIG. 4



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HEAT-SET MECHANICALLY CRIMPED FILAMENTS HAVING DIFFERENT POLYAMIDE COMPOSITIONS

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of our copending application Ser. No. 671,751, filed Sept. 29, 1967 and now abandoned.

BACKGROUND OF THE INVENTION

This invention concerns a continuous filament bulked yarn containing intermingled polyamide filaments of two different types, each derived from stereoisomeric bis(para-aminocyclohexyl)methane (PACM) and its diamine homologs. The invention further concerns fabrics of silklike quality made from these yarns.

Well-known methods have been developed in recent years for crimping continuous filament yarns of synthetic organic polymer to develop greater bulk in the yarn; for example, by false twisting, "stuffer box," knife-edge, or hot gas treatment in a turbulent jet. In the prior art numerous references disclose the simultaneous treatment of two types of yarn in a crimping device. While the known art describes crimping processes for mixed filament yarns, very little effort appears to have been made to establish optimum mixtures for crimping to obtain a combination of high bulk and persistent crimp.

Mixed filament yarns are also known which develop bulk spontaneously without the application of mechanical crimping forces. In general these yarns provide a very desirable softness to textile fabrics but they do not provide sufficient bulk for use in certaln types of fabrics, which should desirably resemble soft silk fabrics such as crepe de chine or broadcloth. In addition, these yarns in the absence of mechanical crimping tend to lose their bulky quality when subjected to tensile forces in the fabric.

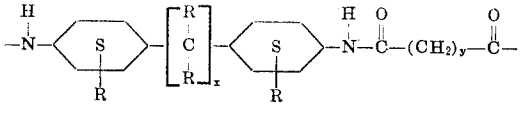
Now it has been discovered that an improved bulky yarn is obtained by applying mechanical crimping to mixed yarns wherein at least two types of PACM polyamide filament are present.

In the course of developing the bulked mixed filament yarns of the present invention for use in silklike fabrics, it has become apparent that the composition of each constituent and the matching of the two filament types is important in obtaining high bulk and resistance to crimp removal under conditions experienced in fabric weaving, drying, dyeing or heat-setting.

SUMMARY OF THE INVENTION

The present invention provides improved bulky yarns of mixed composition suitable for the preparation of "supple," "lively,"synthetic fabrics with stable structure.

The yarn of the invention is a heat-set mechanically crimped yarn of continuous organic polymeric filaments containing at least two types of intermingled thermoplastic polyamide filaments in the filament bundle, the two types of filament in the bundle being characterized by different average lengths in a given length of bulked yarn, at least 50 percent by weight of the repeating units in each of said types of filaments in the mixed filament yarn being characterized by the formula:



wherein x is 1 or 2, y is an integer in the range of 9—14, R is the same or different member of the class consisting of hydrogen and methyl, S stands for saturated, at least 40 percent by weight of the diamino constituent being of a trans-trans stereoisomeric configuration, the crimp index of the yarn being in the range of 2 to 25 percent, and the two types of crimped filament in the bundle having a difference in filament length of at least 5 percent. Preferably the filaments in the mixed filament yarn have an average crimp frequency of at least 20 per inch, based on extended length. The invention further includes new and useful fabrics made from the yarn of the invention

In a preferred form of the invention the mixed yarn contains filaments of PACM-12 homopolymer and filaments of PACM-12/PACM-I (90/10). The abbreviation "PACM-12" indicates the polyamide derived from bis(para-aminocyclohexyl)methane (PACM) and dodecanedioic acid (12). PACM-12/PACM-I (90/10) indicates a copolymer derived from bis(para-aminocyclohexyl)methane and a mixture of dodecanedioic acid and isophthalic acid (I) in a proper ratio to provide a polymer with 90 percent bis(para-aminocyclohexylmethane) dodecanediamide units and 10 weight percent bis(para-aminocyclohexylmethane)-isophthalamide units. The copolymer contains about 70 percent trans-trans stereoisomer in the diamine. The preferred method of preparation of the mixed yarns for crimping is by "-cospinning," whereby filaments of two polymers are extruded simultaneously from different holes in the same spinneret. In this method, mixing of the two types of filament may be accomplished by proper placement of the spinneret holes. Mixing may also be effected after spinning, for example by passing through an air jet to intermingle the two species. The filaments may also be intermingled by joining two planar swaths on a straight bar or roller and then gathering into a bundle. It should be understood that difference in filament length (DFL) is maximized during crimping when the two or more species of filament are thoroughly intermingled. Passage of two separate ends of yarn through the crimping device will of course provide bulky yarns, but the full DFL will not be obtained. By "intermingled" we mean that the two or more types of filaments in the yarn cannot be readily segregated when the yarn is reduced to zero twist.

The term "heat-set mechanically crimped yarn" is used in this specification to describe yarns wherein crimp has been imposed by use of lateral pressure or tension in the presence of heat. The crimp configuration may, for example, be developed in a stuffer box, gear-crimping device, knife edge crimper, or in false-twisting devices. The filaments in the heat-set mechanically crimped yarns are partially deformed in cross section, but still maintain desirable tensile properties. Examination of individual filaments under a polarizing microscope reveals strains and nonuniformities in shape at frequent points along the length of the filaments. This is evidenced by irregular patterns shown by lines of constant optical retardation. In addition, cross-sectional slices reveal deformation at points along the filaments.

While numerous crimping processes may be used to provide bulk in the mixed filament yarns, the process which is adopted will depend on the particular use for which the yarn is intended. Yarns which are to be used to produce supple, lively fabrics such as broadcloth are preferably crimped by use of torsional crimping such as by passage through a false-twist spindle or a torque jet, the crimp configuration being set by the application of heat to the yarn prior to its entering the spindle or jet. Such yarns have filaments with helical crimp.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic drawing showing an apparatus useful for preparing bulked yarn of this invention.

FIG. 2 is a partially sectional elevation of the false-twisting spindle used in the apparatus of FIG. 1.

FIG. 3 is a longitudinal cross-sectioned view of a torque jet useful for false twist crimping.

FIG. 4 is an end view of the torque jet of FIG. 3.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Referring now to FIG. 1, a false-twisting apparatus suitable for preparing yarns of this invention is shown. A mixed fila-

ment yarn 1 is pulled off from yarn supply package 2, passed over yarn guide 3, through tension discs 4 by means of a pair of driven feed rolls 5. After several turns around feed rolls 5 (one of which is canted), the yarn is carried through slotted heater 6 to false-twist spindle 7. The yarn then passes through spindle 7 and pigtail guide 10 to a pair of driven takeup rolls 11, one of which is canted relative to the other. The difference in speed between takeup rolls 11 and feed rolls 5, divided by the speed of takeup rolls 11, times 100 determines the percent overfeed. Generally, this is about 10 percent. After several passes around the pair of takeup rolls 11 the yarn is carried to driven windup roll 15, being distributed along the windup roll by traverse mechanism 16. The windup roll 15 operates at a slower rate than takeup rolls 11. The percent overfeed from takeup rolls 11 to windup roll 15 is about 10 percent.

As shown in FIG. 2, spindle 7 includes a U-shaped housing 8 and a tubular member 13 mounted at its opposite ends for axial rotation in the housing by means of bearings 12. Tubular member 13, which is rotated by belt 14, has a snubbing roll 18 fixed to its upper end. Snubbing roll 18 is centered over axial yarn passage 17 in member 13. The longitudinal axes of snubbing roll 18 and passage 17 are mutually perpendicular. A guide 10, mounted to the upper end of housing 8, is centered over passage 17 above snubbing roll 18.

In operation, the yarn 1 containing two types of filament as specified by this invention is twisted by means of the rotating spindle 7, which turns at a speed of from 145,000 to 240,000 revolutions per minute. The number of turns applied per inch is governed by the speed of the yarn through the spindle and the revolutions per minute as the the yarn passes through passage 17 of spindle 7. The applied twist backs up along the yarn to feed roll 5. The twisted yarn becomes heated by slot heater 6 and the twist configuration is consequently heat-set in the filaments in one direction of rotation. Meanwhile, above the snubbing roll 18, the yarn is twisted in the opposite direction of rotation without the application of heat. The treated yarn therefore has torsional energy stored within it and tends to wind when one end is released. The yarn residence time in the slotted heater depends upon yarn speed, temperature and length of the heater. For example, yarn residence time is 0.6 second at 83 yards per minute when passing through a 27.6-inch (70-centimeters) long slotted heater at 188° C. with spindle rotating at 180,000 revolutions per minute. In another example the yarn is exposed for 0.9 second at 188° C. when the yarn travels at 55.5 yards per minute while being turned at 180,000 revolutions per minute. The increased bulk which is apparent at the windup roll is derived from permanent crimping of the filaments and from loops which form at lower tensions and which are derived from the torsional energy stored in the yarn by the treatment. A permanent helical crimp is obtained when the twisted filaments are softened by heat. In addition, partial or complete loops and "pigtails" form when the torsional energy is released and filaments unwind. This occurs due to the lowering of tension between the takeup roll and the windup roll. The loops or tails formed by torsional release are not permanent unless subjected to a further heat treatment. On the other hand, the helical crimp is permanent and further heat treatment is not necessary if adequate heat is applied by heater 6.

A commercial Type 553 "Superloft" false-twist texturing machine may be used to provide the crimped yarn of the invention. "Superloft" is a trademark of the Leesona Corporation, Warwick, Rhode Island.

FIGS. 3 and 4 shown cross-sectional and end views, respectively, of a representative torque jet 19 which may be used in place of spindle 7 (FIG. 1). In this jet, axial yarn passageway 20 is substantially cylindrical in form throughout its length. A conduit for fluid 21 intercepts the yarn passageway at 22 at an angle of about 90° to the axis thereof and is positioned so that the longitudinal axis of the fluid conduit 21 does not intersect the longitudinal axis of yarn passageway 20, as shown in FIG. 4. When gas under pressure is passed through fluid conduit 21 so that it reaches at least ½ sonic velocity upon emerging into the yarn passageway 20, sufficient torque is applied to the yarn to produce a high rate of crank twisting provided the yarn is maintained at a tension of less than about 15 grams. At relatively high fluid velocities less dense fluids may be employed to obtain substantially the same torque produced by a higher density fluid traveling at lower velocity. Fluid may be supplied to the fluid conduit 21 by any convenient means. FIG. 4 illustrates direct twisting of a filament bundle 23 in yarn passageway 20 and shows, by arrows, that the yarn twists about its axis in the same direction as fluid flow about the inner periphery of the yarn passageway while the axis of the yarn bundle describes a surface 24 spaced from the inner surface of the yarn passageway by a distance at least the radius of the yarn bundle both surfaces having a common longitudinal axis.

To obtain a high crimp index (high elongation due to crimp), it is essential to maintain the filament crystallinity as low as possible up to the point of false twisting. This, of course, must be accomplished without sacrificing other desirable filament tensile properties such as tenacity and toughness.

Torsional crimping of the filaments as described in the examples involves normal processing considerations. The amount of applied false twist is dictated by the crimp frequency needed for desired fabric stretch and aesthetics. Both crimp frequency and crimp index increase with twist. Twist levels above 40 turns per inch are preferred. Once twist level has been specified, the remaining texturing variable such as feed and temperature are adjusted for optimum crimp index. The rat of feed to the spindle controls prespindle tension and also postspindle tension at a given windup rate. If postspindle tension is too high, this reduces the crimp index because of pullout of loops or "pigtails." If tensions are too low, again crimp index is lowered and lightly bulked spots can form due to nonuniform twist slippage around the snubbing roll 18. For each combination of twist and feed rate there is a temperature at which crimp index is at a maximum and postspindle tension is at a minimum. An abrupt increase in tension with temperature is an indication of lubrication failure of the texturing finish used on the yarn. The temperature at which this occurs varies with type and amount of finish and with spindle tension. The higher the spindle tension, the lower the temperature at which failure occurs.

Of course, proper texturing processability requires an effective lubricating finish to be present on the filaments. Preferably, the finish should not fume or be flashed off at the temperature encountered by the yarn during processing. Such finishes may be applied to the filaments during spinning or overlayed on the filaments after spinning and drawing but before texturing.

Optimum texturing conditions for any given yarn will depend upon not only the factors discussed above but also upon the particular machine, position and atmospheric conditions used at the time.

FABRICS

The fabrics of the invention are either of warp or weft knit or of woven construction. The fabrics are constructed of mixed filament yarn containing two types of intermingled filaments, each type being derived from bis(para-aminocyclohexyl)methane and dibasic acids containing at least 11 carbon atoms in the molecule. At least 50 percent by weight of the yarn in the fabric must have this chemical composition. In addition, at least 30 percent by weight of the yarn in the fabrics must be heat-set mechanically crimped. The fabrics of the invention are constructed of yarn having deniers between 20 and 200. Deniers of 20 to 60 are preferred for warp knitting somewhat higher deniers for broad weaving (30 to 120 denier) and still higher deniers (60 to 200) for weft knit.

The preferred fabric construction is plain weave broadcloth for use in blouses. In these fabrics 60 to 110 ends per inch of 60 denier yarn may be used in the warp (denier being that of the unbulked yarn) and 100 to 50 picks per inch may be used

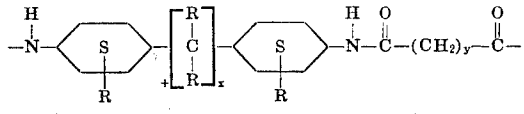
in the filling (weft) of 60 denier yarn. Broadcloth fabrics of the invention have weights in the range of 1.5 to 2.5 oz./yd.^{2}.

While a variety of mixed filament yarns derived from PACM may be used in the fabrics of this invention, it is especially preferred that PACM 12 homopolymer filaments be included in yarns throughout the fabric.

FEED YARNS

A variety of filament types may be blended in the mixed filament yarns of this invention. While a preferred embodiment comprises a mixture of PACM-12 homopolymer filaments with PACM-12/PACM-I copolymer filaments other differences in composition may be used to give the required differential thermal shrinkage and improved crimpability during processing. For example, the two types of polymer may simply differ in relative viscosity in amount of trans-trans stereoisomers, in orientation index, or in chain length of the diacid constituent or in combinations of these factors.

In this section, several kinds of mixed filament yarns are illustrated which are suitable for use in the mechanically crimped yarn of the invention. In each such yarn at least 50 percent by weight of the repeating units in each of the two or more types of filament in the yarns fall within the Formula I:



wherein x is 1 or 2, y is an integer in the range of 9—14. R is the same or different member of the class consisting of hydrogen and methyl, S stands for saturated, at least 40 percent by weight of the diamino constituent being of a trans-trans stereoisomeric configuration. In addition, one of the filament types consists of a member of the class comprising items A through E:

A. A polyamide copolymer containing from 50 to 95 mol percent of the repeating units of formula (I) and 5 to 50 mol percent of another polyamide repeating unit prepared from a member of the class consisting of (1) the same diamine as employed for production of formula (I) repeating unit with a different dicarboxylic acid and (2) the same dicarboxylic acid as employed for production of the formula (I) repeating unit with a different diamine;

B. a polyamide consisting essentially of the repeating units of formula (I) but differing from the polyamide constituting said first group of filaments in the steric configuration of the diamino constituent by at least 10 percent by weight in a steric form;

C. a polyamide consisting essentially of the repeating units of formula (I) and having a relative viscosity (as hereinafter defined) that is at least about 9 units less than that of the polyamide constituting the said first group of filaments;

D. a polyamide consisting essentially of the repeating units of formula (I) wherein the chain length of the diacid constituent of the repeating units constituting the said second group of filaments is less than the chain length of the diacid constituent of the repeating units constituting the said first group of filaments; and

E. a polyamide consisting essentially of the repeating units of formula (I), the said second group of filaments having an Orientation Index (as hereinafter defined) that is at least about 1.0 greater than that of said first group of filaments.

It should be understood, however, that regardless of the type of mixture the false-twisted heat-set, mixed filament yarns should have a crimp index of 2 to 25 percent, a difference in filament length of at least 5 percent and the filaments should have a crimp frequency of at least 20 pr inch, based on extended length.

The diamines of Formula (I), due to their carbocyclic nature, are a mixture of isomers having trans-trans (*tt*), cis-trans (*ct*), and cis-cis (*cc*) configurations. The hydrogenation conditions used in preparing these diamines produce a mixture of isomers, different conditions, of hydrogenation producing a different isomer distribution as shown in U.S. Pat. No. 2,494,563 and U.S. Pat. No. 2,606,924. However, it should be noted that regardless of the relative amounts of (*tt*) and (*ct*) isomers, the amount of (*cc*) isomer does not vary greatly from about 5 percent; thus a statement of the *tt* content of the isomer mixture effectively defines the composition of the mixture. The difference in the amounts of *tt* isomer in the polymers used to prepare the different filaments should be at least 10 percent by weight when no other difference exists. Where larger shrinkage differences are desired, the difference in isomer distribution should, of course, be greater and, in addition to further enchance the shrinkage differential, the molecular weight of the lower *tt* polymer should be higher than that of the higher *tt* polymer.

When a copolymer is used to prepare the higher shrinkage filaments, the *tt* isomer content of the diamine constituent in the homopolymer and copolymer may or may not be the same. It is preferable that the *tt* isomer amounts be substantially the same, however, since this leads to improved spinning performance.

The *tt* isomer content of the polymer used to prepare the low shrinkage filaments should be at least about 40 percent by weight to provide filaments which may be easily processed without excessive shrinkage in hot aqueous solutions as are used in fabric finishing. It will be appreciated, of course, that unless the shrinkage of the low shrinkage filaments is quite low, it is impossible to develop the required difference in shrinkage among the filaments and still keep the overall yarn shrinkage at a desirably low level.

TEST METHODS

The crimped filaments, bulky yarns and fabrics of the invention are characterized by the following tests.

Crimp Index is a measure of the amount of elongation available due to crimp. It is determined on a skein of boiled-off yarn. The skein is prepared by winding under a tension of 0.2 grams per denier (based on extended yarn denier). A 5,000 denier skein is prepared. The skein is conditioned by boiling in water for 15 minutes while supporting a 25-gram load (5 mg./denier) and is then dried while under the same tension. The crimped length L_c is then determined still under 25 g. load. Finally, a load of 500 grams is applied and the extended length L_e is determined. Crimp index is then

$$\frac{L_e - L_c}{L_e} \times 100$$

Crimp frequency (based on extended length) in false-twist textured yarns is useful as a means for determining the amount of heat-set twist obtained in the texturing operation. A 2-inch length of yarn is cut from an untensioned length of yarn taken directly from the textured yarn package. The crimp frequency measurement is determined on individual filaments taken from the bundle. In each case the filament is carefully teased form the yarn bundle. It is allowed to unwind and is then mounted in a viewing device with just enough tension to remove any remaining loops or pigtails. The number of crimps in the filament is determined by counting complete cycles from crest to crest in the crimp wave. Small wiggles which are less than one-fourth the diameter of the tensioned yarn bundle are not counted. After the number of crimps has been counted in an individual filament, the filament is extended to remove all crimp and the extended length is measured. The crimp frequency (extended) is then the number of crimps in the filament sample divided by its extended length in inches. The reported crimp frequency is the average for several filaments including a representative number from each type of filaments in the mixed yarn (same approximate percent).

Difference in filament length for the two components of the mixed filament yarn is determined for a length of strand taken

directly from the textured yarn package after first discarding several wraps. A 10-cm. length of strand is cut; then filaments are teased out of the cut piece of strand. The length of each filament is then determined in an extended condition, the ends of the filaments are supported in clamps and the clamps are separated until the filament is under sufficient tension to remove all crimp. This length is then measured. At least five filaments derived from the low-shrinkage structure and five filaments derived from the high-shrinkage structure should be measured in this manner. In the bulked yarns of this invention the filament lengths will fall into two obviously different classes. This difference, of course, is related to the differential shrinkage which occurs in the texturing process for the two types of filament. The percent difference in filament length (DFL) is calculated from the following equation:

$$DFL = \frac{100(L_2 - L_1)}{L_1}$$

where L_2 is the average length of the longer filaments and L_1 is the average length of the shorter filaments.

Relative viscosity (RV) as used herein is determined on a 6.166 percent by weight solution of a PACM polymer in a solvent consisting of a 50 percent by weight of 98—100 percent formic acid and 50 percent freshly distilled phenol. The solvent mixture has a density of 1.126±0.001 grams per cm.^{3} at 25° C. The polymer solution is prepared by dissolving 3.700 grams of ground dry polymer in 50.0 ml. of the solvent. The effluxing time of the polymer solution is then determined in a viscometer maintained at 25 ±0.05° C. The same determination is made for the solvent alone. Relative viscosity is the flow time of the solution divided by the flow time of the solvent.

Orientation Index, as used herein, is a measure of crystalline orientation in the fiber. The orientation of crystallites in PACM polyamide fibers appears to change rapidly when heat is applied in any way. The amount and direction of change may be greatly affected by such factors as torsion, tension, compression, or slack in the fiber during heating. The orientation index is obtained from an X-ray diffraction pattern. The measurement as described herein appears to be more responsive to crystallite changes than is the traditional arc measurement for X-ray diffraction.

The orientation index is determined from a flat-plate wide-angle X-ray diffraction pattern. A flat-plate vacuum camera is used with nickel filtered copper X-rays at 40,000 volts potential and 20 milliamp current, e.g. with a General Electric Company XRD-5 X-ray unit with a CA-8 X-ray tube. The beam is collimated with an outside pinhole diameter of about 0.625 mm. and an inside pinhole diameter of about **0.50** mm. with a separation of 7.0 cm. Careful technique must be employed to assure measurement to the maximum density in both regions which is then corrected by subtraction of the proper background density before the ratio calculation. Analysis of both regions must be made on the same X-ray negative. In making the exposure, care must be taken to assure that the yarn has no twist or crimp when supported in the camera and that all of the filaments in the yarn are aligned in a parallel manner. A yarn sample thickness of no more than about 0.50 mm. is used with a sample to film distance of 7.5 cm. The pattern for the subject fibers shows a well-defined meridional reflection at a Bragg spacing of about 10.4 A and an equatorial diffraction, or amorphous halo, at a Bragg spacing of about 4.7 A. The orientation index is calculated as the ratio of the maximum intensity of this meridional spot divided by the maximum intensity of this equatorial halo. The intensities are measured on the X-ray negatives using conventional microphotometry techniques. The negatives are prepared in a conventional manner using No Screen X-ray film manufactured by Eastman Kodak Company, 1 Rochester, New York (or X-ray film providing equivalent contrast). The film is developed for 3 minutes at 20° C. with Kodak X-ray developer at the concentration recommended by the manufacturer. Exposure times for the X-ray negative should be such that the microphotometer registers optical densities for both regions of less than 1.0 but not less than 0.10.

Similar measurements may be made on filaments other than PACM-12 by using a Bragg spacing characteristic of the particular polymer.

Compressional Compliance is defined as the thickness (T_3) of a fabric in thousandths of an inch under 3 g./cm.^{2} pressure divided by the thickness (T_{230}) of fabric in thousandths of an inch under 230 g./cm.^{2} pressure. This procedure utilizes an ultrasensitive pneumatic gauge to determine the distance between a flat parallel glass loading plate and a reference surface, the fabric being sandwiched between the glass plate and reference surface. High values of T_3/T_{230} indicate high bulk and vice versa.

Filament-in-Fabric Packing Factor (P_{FF}) is a ratio relating calculated fabric thickness (assuming no voids or free space in the fabric) to actual thickness. It is calculated from the formula

$$P_{FF} = 1.36 \frac{w}{pT_3}$$

wherein w is the fabric weight in oz./yd.^{2}, p is the density of the fiber in g./cm.^{3}, T_3 is the fabric thickness in thousandths of an inch under a pressure of 3 g./cm.^{2}, and the constant 1.36 is a factor to convert numerator and denominator to cm. units of thickness.

PREPARATION OF MIXED FILAMENT PACM YARNS

PACM-12 homopolymer is prepared in an autoclave containing 50 parts water and 50 parts of the salt of bis(4-aminocyclohexyl)methane and dodecanedioic acid. The diamine consists of 70 percent of the *tt* isomer.

As a viscosity stabilizer, 12 millimoles of acetic acid are added for each mole of the polyamide slat. The solution also contains 0.005 percent manganous hypophosphite, based on the weight of the salt. This solution is heated in a closed vessel for 2 hours while the temperature is raised to 285° C., a sufficient amount of a 20 percent aqueous slurry of finely-divided kaolinite being added when the temperature reaches 210° C. to provide a concentration of 2 percent by weight of the kaolinite in the final polymer. The pressure is then reduced to atmospheric while the temperature is raised to 315° C. and the polymer held under these conditions for 1 hour. It is then extruded and cut to flake. The relative viscosity of the flake is 45.9.

In a similar fashion, a PACM-12/PACM-I copolymer is prepared from a slat of bis-(4aminocyclohexyl)methane and a mixture of dodecanedioic and isophthalic acids. The mixed acids contain 8.7 percent by weight of isophthalic acid which is sufficient to provide 10 percent by weight, or 12.3 mole percent, of the isophthalic copolymer component in the final polymer. The diamine contains 70 percent of the *tt* isomer, and 6.8 millimoles acetic acid per mole of salt is used. The relative viscosity of the flake is 52.5.

The polymer and copolymer are melted separately at 325° C. in screw-type melters. They are then extruded simultaneously (co-spun) through different holes in the same spinneret at 325° C. The spinneret may have, for example, 18 orifices for one polymer supply and 18 orifices for the other polymer supply. The orifices are arranged in a circular pattern and the two types alternate around the circle. Further details of the apparatus construction are given in U.S. Pat. No. 3,225,534. For the present case the orifice cross section is Y-shaped for each of the orifices in the spinneret. The quenching of the freshly spun filaments is adjusted to provide filaments of trilobal cross section characterized by "lustre highlite" as described in U.S. Pat. No. 2,939,201. The filament deniers are approximately equal for the two-polymer species polymer pump speeds being equal for the two polymers. The filaments may, for example, be extruded at a rate of 0.547 g./min./orifice for a windup speed of 2,700 yards/min. (2,469 m./min.) for a 60 denier 36 filament yarn. Both sets of filaments in the mixed yarn may contain 2 percent by weight of aluminum silicate (kaolinite) to aid in developing the frictional qualities similar to those of silk. The trilobal cross-sectional shape of

the filaments also contributes to the silklike character since more intense luster highlights are obtained. It should be recognized that the different crystallization rates for the two types of polymer may give filaments of differing cross section even though the hole shapes are identical. While this may at times be advantageous, a difference in shape between the two species may be avoided by using a lower relative viscosity in the species which crystallizes fastest (i.e., the PACM-12 homopolymers), and a high viscosity in the slow crystallizing polymer (PACM-12 PACM-I copolymer). The relative viscosity of the polymer in either case changes during spinning because of the effect of moisture in the atmosphere.

In preparing fibers with a specified orientation index various spinning, drawing, and annealing factors must be observed. In general, in the absence of other changes, an increase in orientation index is obtained by use of

a. Higher spin-draw factor, ratio of windup speed to extrusion speed.
b. Higher draw pin or draw roll temperature.
c. Higher draw ratio.
d. Higher annealing temperature.
e. Lower extrusion speed at constant feed roll speed.

In a typical spinning process, the filaments from the two polymer supplies are quenched by exposure to air for 0.014 seconds at 25° C. The filaments are then combined and passed over a finish applicator roll where a conventional lubricating finish is applied. The filaments then pass to a pair of power-driven feed rolls operating in tandem and rotation at a peripheral speed of 800 yds./min. (734 m./min.). The yarn is given six passes around the feed rolls. After the feed rolls, the yarn passes around a draw pin heated at 120° C. and then eight times around a pair of draw rolls having a peripheral speed of 1,680 yds./min. (1,541 m./min.) at 120° C. The draw ratio is 2.1. The yarn then passes eight times around a pair of annealing rolls operating in tandem at a peripheral speed of 1,680 yds./min., (1,541 m./min.), the yarn being heated at 150° 160° C. on these rolls. The yarn is then passed through an air jet to provide a compact loop-free interlaced yarn as described by Bunting and Nelson in U.S. Pat. No. 2,985,995. The yarn is then passed to a pair of unheated rolls. The yarn is permitted to cool as it passes six times around the pair of unheated rolls operating in tandem and rotating at a peripheral speed of 1,689 yds./min. (1,548 m./min.). It is then wound into a package in the conventional manner at 1,650 yds./min. (1,514 m./min.). At this point the denier of the final yarn is 63. The relative viscosity of the homopolymer in one type of filament is 52 and of the copolymer in the other type of filament is 48. The skein shrinkage of the yarn in boiling water with 4 mg./denier load is 9.4 percent and the DFL of the yarn in the boiled off skein is 5.7 percent. When the boiled off yarn is additionally heated in air at 177° C. under 4 mg./denier load, the DFL is 34.5 percent. Total skein shrinkage after boil off (4 mg./den.) and heat treatment at 177° C. (4 mg./den.) was 17.0—17.9 percent. When a yarn skein is boiled off under 4 mg./denier load and heat-set at 177° C. under 16 mg./denier load, the skein shrinkage is about 10.5 percent and the filaments have a DFL of about 5.5 percent.

EXAMPLE I

A 60 denier interlaced mixed filament PACM yarn is subjected to false twist crimping on a "Superloft" machine shown diagrammatically in FIG. 1. Both sets of filaments in the mixed filament yarn of this example contain 2 percent by weight of aluminum silicate (kaolinite) to aid in developing the frictional qualities similar to those of silk. The filaments have trilobal cross-sectional shape which also contributes to the silklike character since more intense "luster highlights" are obtained. The yarn is composed of 18 filaments of PACM-12 polyamide and 18 filaments of PACM-12/PACM-I (90/10) polyamide. The yarn is fed at a speed of 76 meters/min. through a heater tube which is 73.7 cm. long, passed around the snubbing roll of a spindle rotating at 180,000 revolutions per minute to a set of takeup rolls operating at 68.4 meters per min., and finally wound up on a package at a speed of 65.0 meters per min. The feed rate to the spindle is 10 percent greater than the discharge rate from the spindle. The postspindle tension is 13 to 28 grams. The temperature (at the inner surface) of the heater tube is adjusted to promote maximum softening of the mixed filament yarn without melting or stretching of the filaments and without appreciable loss of tensile strength. The speed of spindle rotation and the feed rate is sufficient to subject yarn to 60 turns per inch of twist. This textured mechanically crimped yarn is wound up at 13 to **18** grams tension. After texturing by the above described method the textured yarn has a difference in filament length of 9.5 percent as removed from the package. The crimp index was 7.0 percent and the crimp frequency was 41/inch, based on extended length.

Several additional samples of the same mixed yarn were passed through the same apparatus at different spindle or takeup speeds to obtain spindle twist levels of 50, 60, 70, and 80 turns per inch. The effect of increasing twist level on crimp index and crimp frequency on textured yarn is shown in Table I and demonstrates the superior crimpability (as measured by crimp index or crimp frequency) of mixed filament yarns derived from PACM and its homologs compared to similar mixed filament yarns composed of filaments of 6–6 homopolymer and filaments of 6–6/6—I copolymer.

TABLE I.—PROPERTIES OF FALSE-TWIST-CRIMPED YARNS

Yarn type	Crimp index, percent	Crimp frequency, crimps/inch (extended)
Mixed yarn of 6–6 and 6–6/6–I (90/10):		
50 turns/inch	1.6	24
60 turns/inch	3.5	28
70 turns/inch	4.5	47
80 turns/inch	4.3	43
Mixed yarn of PACM–12 and PACM–12/PACM–I (90/10):		
50 turns/inch	4.6	36
60 turns/inch	7.0	41
70 turns/inch	12.8	49
80 turns/inch	10.1	52

The mixed filament crimped yarn containing PACM-12 and PACM-12/PACM-I filaments retained its bulk and crimp structure is subsequent processing to form fabrics as shown in example II. The homopolymer 6–6 is prepared from hexamethylene diamine and adipic acid. The copolymer 6–6/6—I is prepared from hexamethylene diamine, adipic acid, and isophthalic acid in a proportion sufficient to give 10 percent by weight of 6—I structural units and 90 percent of 6–6 structural units. The mixed 6–6 and 6–6/6—I yarns were cospun, drawn, and interlaced. Then the interlaced yarn was false twisted using temperatures consistent with the 6–6/6—I melting point. The 6–6 and 6–6/6—I filaments after bulking at 60 turns per inch and skein boil off (4 mg./den.) had a differential filament length of only 2.0 percent. The PACM-12 and PACM-12PACM-I filaments bulked at 60 turns per inch had a difference in filament length of 9.5 percent. The PACM-12/PACM12PACM-I yarn prior to crimping had a DFL (boiled off with 4 mg./den. load) of 5.7 percent. The increase in DFL with mechanical crimping and heat-setting is apparently responsible for the development of high bulk in fabrics as shown in example II.

EXAMPLE II

A number of woven fabric samples were prepared using the 60 denier, 36 filament interlaced yarn of example I containing filaments of PACM-12 homopolymer and PACM-12/PACM-I copolymer. In each fabric the mixed filament yarn was used in both warp and filling (weft). In the warp direction the interlaced yarn was used either with or without false-twist crimping as shown in Table II. In the filling direction false-twist crimped interlaced yarn was used in each fabric. The warp yarns with false-twist texturing were used without applying any true twist.

The uncrimped interlaced warp yarns were, however, given 5 turns per inch twist in the Z direction.

For the filling direction of the fabric, the yarn was false-twist crimped to produce either S or Z torque as indicated in Table II. It should be understood that the direction of torque refers to the direction of twist in the portion of the process wherein heat is applied. Cut filaments will revert to this configuration if both ends are released, or if the tension is reduced to permit formation of loops or pigtails. For example, when the yarn is false-twisted in the Z direction, release of the ends will permit the yarn to windup in the Z direction to release torque.

In this example the same mixed filament yarn was used for the first five items shown in Table II (Items *a* through *e*). The various fabrics differed in construction on the loom, in applied twist, and in the presence or absence of a texturing step. In Item *f* a 30 denier yarn was prepared having 9 filaments of homopolymer and 9 filaments of copolymer. The preparation of the Item *f* yarn was otherwise the same as for Item *a*.

The fabrics constructed with loom ends/inch and loom picks/inch as shown in Table II were finished by a sequence of processes comprising scouring the fabric in skein form in boiling water for one hour, passing through a Famatex machine to dry at 107° C. for 30 seconds, heat-setting in a Famatex tenter at 174° C. with 30 seconds exposure at full fabric width and 5 percent overfeed, dyeing in a beck at the boil, heat-setting again in a Famatex tenter for 2 minutes at 182° C., and finally semidecating with steam for one minute and with vacuum for one minute. The finished pick and end count is indicated in Table II.

The resulting fabrics all showed a high degree of bulk and softness as evidenced by the low filament-to-filament packing fraction in Table II. At the same time the fabrics each had a relatively high compressional compliance correlating with textile softness. Subjective evaluation of liveliness and suppleness indicated that the fabrics of Table II were substantially equivalent to similarly constructed silk crepe de chine fabrics. In addition, the fabrics of Table II retained their softness and filaments retained crimp even when subjected to high tensile loads. The fabrics likewise had a high degree of resilience, and returned rapidly to their unstressed configuration when tension was released.

EXAMPLE III

A "cospun" yarn prepared by a method similar to example I and having the same composition was bulked by a compressional crimping process. The yarn was passed through a "stuffer box" of a type described in U.S. Pat. No. 3,110,076. The yarn was passed upward through a pair of feed rolls which had an axial length of 0.99 cm. and a diameter of 3.2 cm. A force of 1.1 kg. was applied between the two rolls. The yarn was passed from the nip of the rolls into a crimping chamber where it collected in zigzag fashion. A retarding force of 17 g. was applied by means of cylindrical steel slug whose weight rested against the collected yarn emerging from the nip of the two rolls. The cylindrical slug fit loosely inside the crimping chamber above the rolls, the chamber being 0.95 cm. in diameter and 20.4 cm. in length. The crimping chamber was heated to a temperature of 210° C. by external electrical heaters. The yarn emerged through an axial hole in the center of the cylindrical steel slug, the hole being about 0.3 cm. in diameter. It emerged from the crimping chamber and was withdrawn by a pair of rolls operating at a speed of 234 meters/min. and was wound up at a tension of 6 to 8 g.

A crimped yarn was obtained having filaments with angular zigzag crimp. The crimp index was 6.3 percent after boil off under a load of 5 mg./denier. The difference in filament length was 8.6 percent. The crimp frequency was greater than 20 crimps/inch (extended). The crimp structure was substantially retained through weaving and finishing. The crimp was "zigzag" (angular folded) in configuration before weaving.

TABLE II.—FABRICS CONSTRUCTED FROM MIXED YARNS OF THE INVENTION

Item	Warp yarn	Ends/inch		Filling yarn	Picks/inch		Weight, 2 oz./yd. finished	Compressional compliance, $T3/T_{230}$	Fiber-in-fabric packing factor, $1/\epsilon_F$
		Loom	Finished		Loom	Finished			
a	Untextured 60-36, 5 turns/inch Z real twist	86	101	Textured 60-36, false twist S for 2 picks, then Z for 2 picks	76	98	1.9	1.26	0.225
b	Untextured 60-36, 5 Z real twist	100	115	Textured 60-36, same as *a* filling	62	75	1.8	1.34	0.242
c	Untextured 60-36, 5 Z, real twist	72	86	Textured 60-36, same as *a* filling	90	102	1.7	1.25	0.222
d	Untextured 60-36, 5 Z, real twist	86	103	Textured 60-36, false twist alternated S and Z for every pick	76	93	1.8	1.21	0.263
e	Textured 60-36, false twisted 60 turns/inch, alternate 2 ends false S and 2 ends false Z. In each use 5 turns real Z twist added.	86	98	Textured 60-36, picks as in *a* filling	76	92	1.8	1.29	0.245
f	Untextured 30-18, 5 turns/inch, real Z twist	130	140	Textured 60-36, picks as in *a* filling	76	105	1.7	1.21	0.290

EXAMPLE IV

Mixed filaments of the same composition as those in example III may be crimped in a stuffer box of a type described in U.S. Pat. No. 3,200,466 to obtain a bulked yarn with a somewhat lower crimp index than is obtained in the apparatus of example III. The retarding force in this case is provided principally by weight of bulked yarn standing in the cylindrical tube and by friction between the yarn and the tube. The rate of feed into the crimping cylinder is regulated by control of the feed roll speed. This speed is, in turn, controlled by a wire loop feeler which passes through a slit in the side of the crimping chamber. The feeler operates a mercury switch which in turn controls the electric power supplied for the motor operating the feed rolls. A pair of takeup rolls continuously withdraws the crimped strand from the crimping chamber at a constant rate. The volume of yarn in the crimping chamber is, therefore, maintained at an approximately constant level. The retarding force exerted in this type of apparatus is considerably less than in example III. In a typical operation of the apparatus a product was obtained having a folded crimp structure (zigzag), a crimp index of 2.2 percent, a differential filament length of 15.2 percent, and a crimp frequency above about 10 crimps/inch (based on extended length). Fabrics prepared from this yarn had a desirable soft handle similar to silk. Crimp structure was substantially retained through the weaving and finishing processes.

EXAMPLE V

A yarn containing 17 filaments of PACM-12 and 17 filaments of PACM-12/PACM-I (90/10) was prepared according to the method of example I. The filaments from the two polymers were quenched, combined, drawn, annealed, and interlaced as in example I. The drawn cospun yarn was 65 denier and was similar in properties to the yarn prepared in example I. This yarn was subjected to torsional crimping using a torque jet. High pressure air was introduced to the jet to provide a twisting action on the mixed cospun yarn. The jet was mounted on a standard "Superloft" 553 false twisting machine. Referring to FIG. 1, the false twisting spindle 7 was replaced by the torque jet shown in FIGS. 3 and 4.

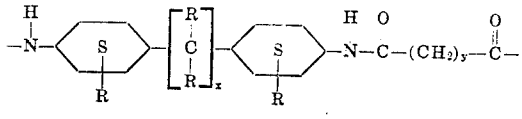
The yarn was fed into the torque jet at a speed of 80 yds./min. (73.4 m./min.). The optimum crimping conditions were sought by varying the temperature of the slotted heater 6, and by varying air pressure in the torque jet. The highest crimp index value was obtained at 80 lbs./in.^{2} gage (6.6 kg./cm.^{2} gage) and at 400° F. (204° C.) Other conditions are shown in Table III.

TABLE III

Item	Jet Pressure lbs/in^2 gage (kg/cm^2)	Overfeed, percent	Temperature °C.	Crimp Index	Crimps/in.
1	60 (4.2)	10	176	10.8	34.6
2	60 (4.2)	10	204	11.1	.....
3	60 (4.2)	10	232	2.8	.....
4	80 (5.6)	10	176	11.0	36.3
5	80 (5.6)	10	204	16.4	31.3
6	80 (5.6)	10	232	4.1	.....

What we claim is:

1. A heat-set mechanically crimped yarn comprising a plurality of continuous organic polymeric filaments containing at lest two types of intermingled thermoplastic polyamide filaments, each of said types being constituted at least 50 percent by weight of repeating units characterized by the formula:



I

wherein x is 1 or 2, y is an integer in the range of 9—14 and R represents the same or different member of the class consisting of hydrogen and methyl, at least 40 percent by weight of the diamino polymer constituent being of a trans-trans stereoisomeric configuration, said two types of filaments having a DFL of at least 5 percent, said yarn having a crimp index of from about 2 to approximately 25 percent.

2. The yarn of claim 1 characterized in that one of said types of filaments consists essentially of the repeating units of the formula I, and the other of said types being constituted of a member of the class consisting of:

A. a copolyamide containing from 50 to 95 mol percent of the repeating units of formula (I) and 5 to 50 mol percent of another polyamide unit prepared from a member of the class consisting of (1) the same diamine as employed for production of formula (I) repeat unit with a different dicarboxylic acid and (2) the same dicarboxylic acid as employed for production of the formula (I) repeat unit with a different diamine,

B. a polycarbonamide consisting essentially of the units of formula (I) but differing from the polycarbonamide constituting said first group of filaments in the steric configuration of the diamino constituent by at least 10 percent by weight in a steric form,

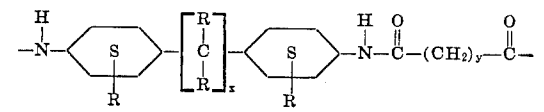
C. a polycarbonamide consisting essentially of the units of formula (I) and having a relative viscosity that is at least about 9 units less than that of the polycarbonamide constituting the said first group of filaments,

D. a polycarbonamide consisting essentially of the units of formula (I) wherein the chain length of the diacid constituent of the polymer units constituting the said second group of filaments is less than the chain length of the diacid constituent of the polymer units constituting the said first group of filaments, and

E. a polycarbonamide consisting essentially of the units of formula (I), the said second group of filaments having an Orientation Index that is at least about 1.0 greater than that of said first group of filaments.

3. Yarn of claim 1, said yarn being torsionally crimped and characterized by a crimp frequency of at least 20 crimps per inch based on extended length.

4. A heat-set mechanically crimped yarn comprising a plurality of continuous organic polymeric filaments containing at least two types of intermingled thermoplastic polyamide filaments, one of said types consisting essentially of repeating polymeric units characterized by the formula:



I

wherein x is 1 or 2, y is an integer in the range of 9—14 and R represents the same or different member of the class consisting of hydrogen and methyl, the other of said types being constituted by a copolyamide containing 90 mol percent of the repeating units of formula I and 10 percent of another polyamide unit prepared from a member of the class consisting of (1) the same diamine as employed for the production of formula I repeat unit with a different dicarboxylic acid and (2) the same dicarboxylic acid as employed for the production of formula I repeat unit with a different diamine, said two types of filaments having a DFL of at least 5 percent, said yarn being characterized as to elongation due to crimp by a crimp index of from about 5 to approximately 13 percent and having a crimp frequency of from about 36 to 52 crimps per inch based on extended length.

5. The yarn of claim 4 characterized in that y is 10 and said different dicarboxylic acid is isophthalic acid.

6. A fabric construction characterized by at least 30 percent by weight of the yarn defined in claim 5.