

Oct. 20, 1970

D. H. EDISON

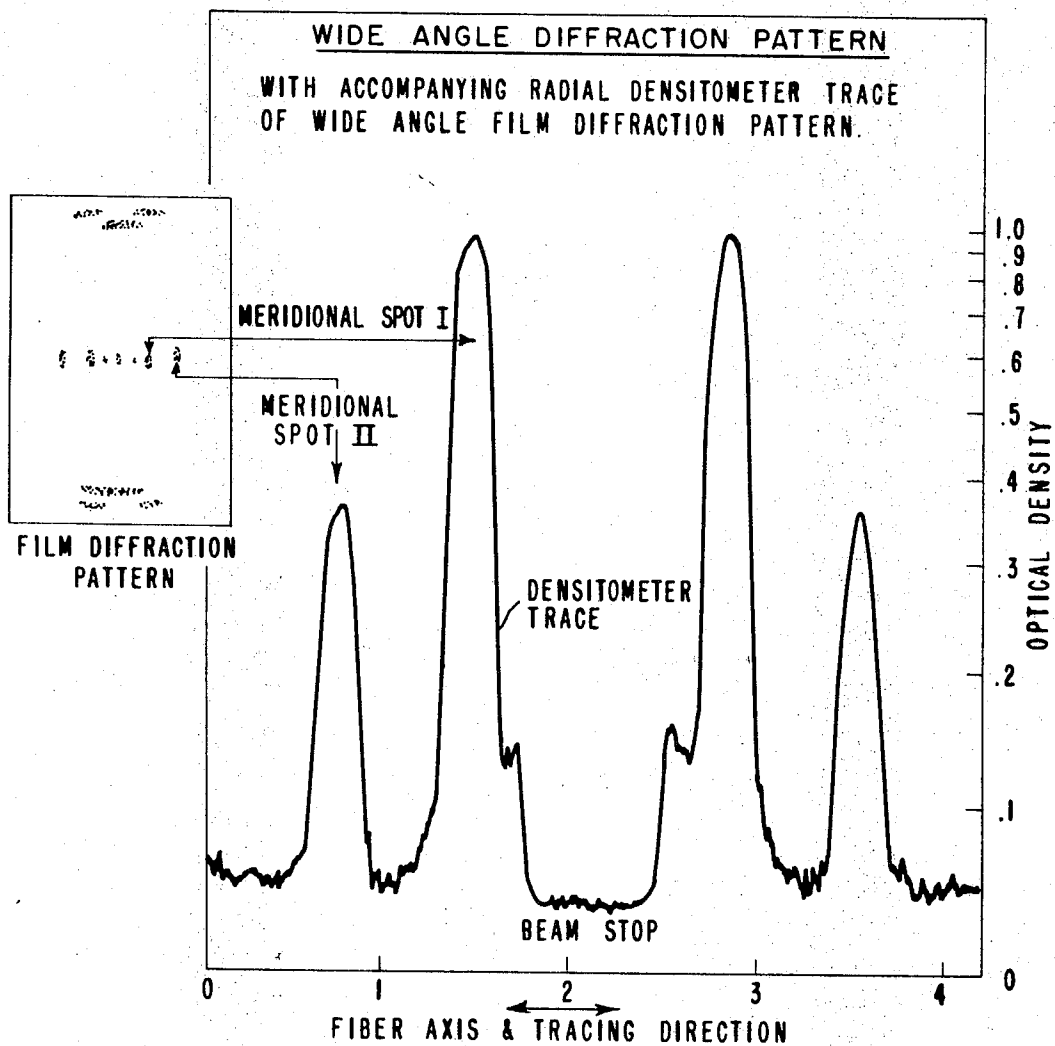
3,534,541

CRIMPED YARN AND PROCESS OF MAKING SAME

Filed July 15, 1969

2 Sheets-Sheet 1

## FIG. 1



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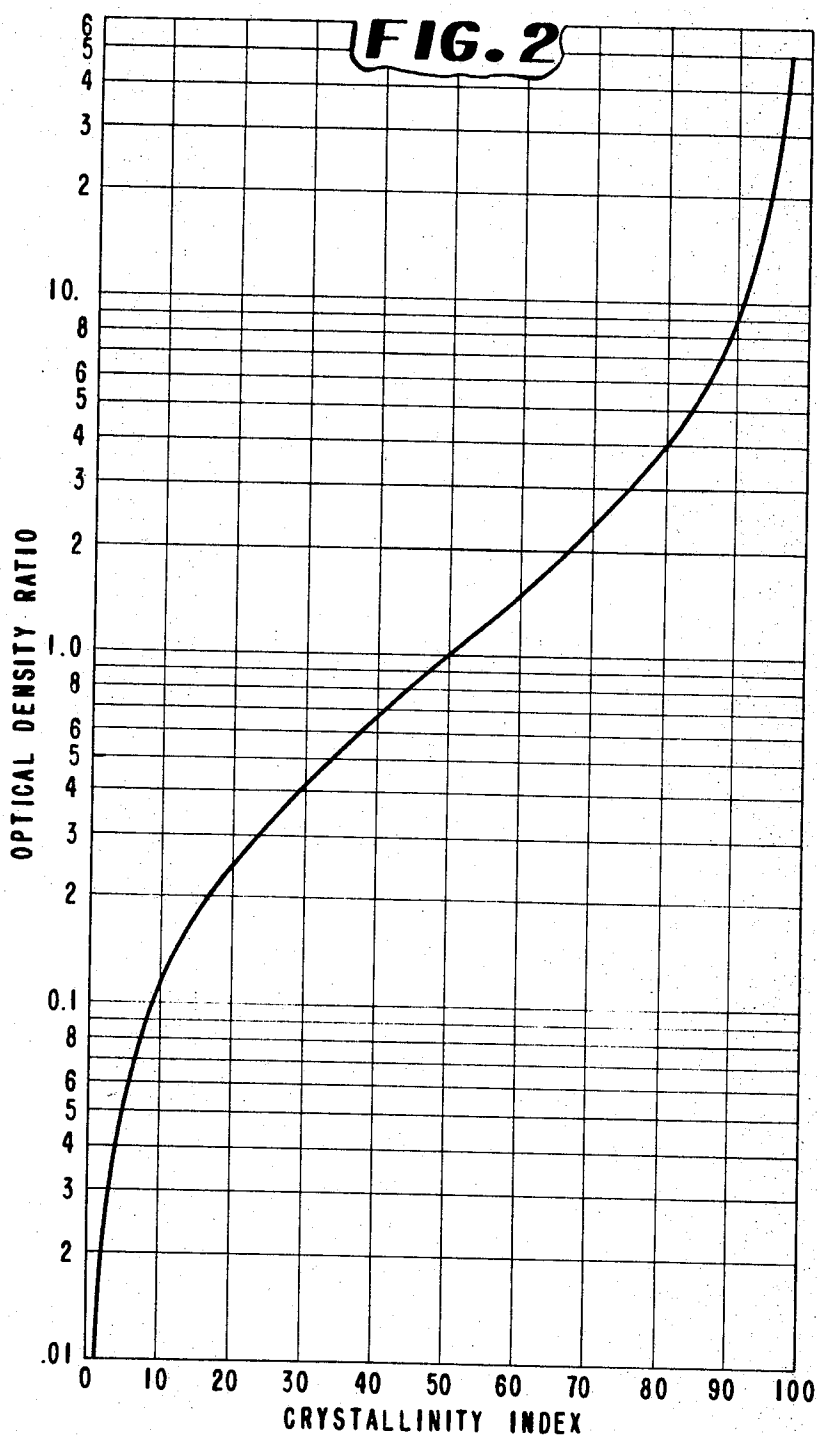
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2 Sheets-Sheet 2



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3,534,541

**CRIMPED YARN AND PROCESS  
OF MAKING SAME**

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to E. I. du Pont de Nemours and Company, Wilmington,  
Del., a corporation of Delaware  
Continuation-in-part of application Ser. No. 716,867,  
Mar. 28, 1968. This application July 15, 1969, Ser.  
No. 841,747

Int. Cl. D02g 1/02, 3/02

U.S. Cl. 57—140

14 Claims

**ABSTRACT OF THE DISCLOSURE**

A process for texturing a feed yarn having a plurality of continuous filaments constituted of repeating polymeric units of bis(4-cyclohexylene) methane dodecanediamide, wherein from 45–100% of the bis(4-cyclohexylene) methane portion of the unit is in the trans-trans isomer form, with a relative viscosity of at least 40 and a Crystallinity Index of less than 20. The feed yarn is subjected to a temperature of at least 160° C. under texturing conditions to increase the crystallinity index. The textured yarn after cooling is characterized as to elongation due to crimp by a Crimp Index greater than 30% and is further characterized as to relative crystallinity by a Crystallinity Index of at least about 40.

**CROSS-REFERENCE TO RELATED APPLICATION**

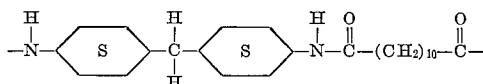
This is a continuation-in-part of my pending application Ser. No. 716,867, filed Mar. 28, 1968 and now abandoned.

**BACKGROUND OF THE INVENTION**

This invention pertains to a process for texturing continuous filaments of poly[bis(4-cyclohexylene)methane dodecanediamide], a polymer derived from bis(4-amino-cyclohexyl) methane and dodecanedioic acid, and improved textured yarns produced thereby.

Methods are well-known whereby continuous filament yarns of synthetic, thermoplastic polymers can be mechanically processed to alter their texture and bulk. Commonly this involves heating and cooling them in a crimped or twisted condition, for example the well-known heated stuffer box crimping and false-twist texturing processes. A major limitation in the development of improved textured yarns is the problem of having filaments which are sufficiently responsive to heat under texturing conditions without loss of desirable tensile properties coupled with an ability of the textured filaments to retain their textured qualities in subsequent processing and use.

Filaments of polycarbonamides from bis(4-aminocyclohexyl)methane, hereafter referred to as PACM, and certain linear aliphatic dicarboxylic acids are known which have outstanding resilience and recovery properties. Such polymers are described for example in U.S. Pat. No. 2,512,606 to Bolton and Kirk and U.S. Pat. No. 3,249,591 to Gadecki and Speck. Filaments from polymers of PACM and the 12-carbon dodecanedioic acid, hereafter referred to as PACM-12 and characterized by the formula:



are particularly outstanding in this respect as described in U.S. Pat. No. 3,393,210 issued July 16, 1968.

**SUMMARY OF THE INVENTION**

Objects of this invention are improved textured yarns of PACM-12 having an outstanding combination of tex-

tured and tensile yarn properties and an improved process for producing such yarns.

The objects of this invention are realized by a process for mechanically texturing a feed yarn comprising a plurality of continuous substantially straight filaments constituted at least 50% by weight of repeating polymeric units of bis(4-cyclohexylene) methane dodecanediamide (PACM-12) with at least 45% of the bis(4-cyclohexylene) methane (PACM) portion of the units being in the trans-trans isomer form. The filaments, having a relative viscosity of at least 40 and a Crystallinity Index of less than about 20 are mechanically distorted from the straight configuration then heated in the distorted configuration by subjecting them to a temperature of at least about 160° C. until the Crystallinity Index increases to at least about 40 and then cooled, resulting in filaments having improved crimp and crimp retention properties.

A preferred process embodiment comprises a process for false-twist texturing continuous, substantially straight filaments of PACM-12 containing at least 60% of the trans-trans PACM isomer, having a relative viscosity greater than 45, a Crystallinity Index less than about 20 and greater than about 5 and a denier per filament of from about 1 to about 8 comprising the steps of twisting the filaments to at least 50 turns per inch (t.p.i.) (19.7 per cm.), heating the twisted filaments to a temperature above about 160° C. until the Crystallinity Index increases to at least about 50, cooling and untwisting the filaments in a continuous operation to give an improved false-twisted yarn having outstanding power, stretch and recovery properties.

A preferred product of this invention is a false-twisted, textured yarn comprised of continuous, oriented filaments of PACM-12 containing at least 60% of the trans-trans PACM isomer, having a relative viscosity greater than 45, a denier per filament from about 1 to about 8, a Crystallinity Index greater than 50 and a Crimp Index greater than about 30.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 shows a typical densitometer trace of a typical fiber X-ray film diffraction pattern used in determining the relative crystallinity of yarns in this invention. FIG. 2 is a graph which relates the ratio of the X-ray diffraction spot intensities or optical densities shown in FIG. 1 to the Crystallinity Index used herein, which is a convenient value for comparing relative degrees of fiber crystallinity.

**DETAILED DESCRIPTION OF THE INVENTION**

Filaments useful in the process of this invention are prepared from PACM-12 polymers by conventional melt-spinning and drawing processes. The spinning and drawing may be performed in a continuous, coupled process or in separate steps by a split process.

The polymers are conveniently prepared by normal melt condensation polymerization processes from PACM containing from 45–100% of the trans-trans isomer and dodecanedioic acid. Copolymers of PACM-12 containing minor amounts of other polycarbonamide units are included provided the copolymers remain capable of meeting the initial crystallinity requirement and of undergoing a change in crystallinity as described herein. The concentration of such copolycarbonamide units permissible varies depending upon the extent to which such units interfere with polymer crystallinity. Concentration of copolymeric units as high as 40% may be permissible when such units closely resemble the basic PACM-12 units in their nature, for example wherein they differ only by use of another aliphatic, linear dicarboxylic acid, such as adipic or sebacic acids, with PACM. Conversely, only very low concentrations, for example less than 10%, may be per-

missible when such units differ widely in character from that of the basic PACM-12 polymer, such as with copolymeric units consisting of PACM and isophthalic acid.

In general, to realize maximum benefit of this invention, the polymer must contain at least about 50% by weight of the repeating units of the PACM-12 composition, said units containing at least 60% of the trans-trans PACM isomer. Normally, filaments from polymer containing higher concentrations of the trans-trans PACM isomer give higher crimp indices than do filaments from polymers containing a lower concentration of the trans-trans PACM isomer. Similarly, homopolymers tend to more readily undergo the desired increase in crystallinity than do copolymers, and consequently homopolymers are usually preferred. As used herein, polymers prepared from a mixture of PACM isomers within the limits prescribed and dodecanedioic acid are considered as homopolymers even though they are prepared from a mixture of isomeric PACM diamines.

"Mechanical texturing" as employed herein includes any texturing process wherein the filaments are mechanically distorted from a straight configuration by external forces and heat-set in the distorted configuration in order to increase their bulk. This includes such well-known texturing processes as heated stuffer box crimping, gear crimping and false-twisting provides the filaments are subjected to a temperature above about 160° C. for a sufficient time to induce the increase in crystallinity as prescribed. In order to bring about the desired increase in crystallinity, the filaments must be subjected to a temperature above about 160° C. Temperatures higher than 160° C. are preferred because of the more rapid rate of crystallization; however, the temperature must not be so close to the polymer melting temperature that a significant loss in tensile properties is incurred.

The actual time of heating and temperature to which the filaments are exposed during texturing will vary considerably depending upon the type of heating employed and efficiency of the heating process. Of course for short exposure time the filaments may be subjected to much higher temperatures than would otherwise be possible provided the exposure time is not so long as to result in fusing of the filaments or the detrimental effects of thermal degradation. Normally, the temperature should be less than about 238° C. Obviously, the higher the temperature, the shorter the time of exposure required. Heating of the filaments may be performed by radiation, conduction or induction heating processes; e.g. by contact with heated fluids or heated surfaces.

The benefits of this invention require that the filaments initially have a low degree of crystallinity measured as defined herein by having a Crystallinity Index of less than about 20, preferably 15. Such filaments have been found to have a surprising responsiveness under conventional texturing conditions such that the yarns may be handled in a normal manner on conventional equipment, but with surprising results with respect to the efficiency of the process in producing highly textured yarns. The resulting filaments have an outstanding combination of textured and tensile yarn properties.

The filaments may be processed in a stepwise operation, e.g. twisting, packaging and heating in packaged form, or in a continuous manner. However, due to the surprising responsiveness of the feed yarn described herein, the process is particularly suitable to continuous operations wherein the yarn is processed at relatively high speeds involving exposure to high temperature for a short period of time, for example less than 1 second, as encountered in commercial continuous false-twist texturing operations as described for example in U.S. Pats. Nos. 2,803,109 and 3,079,745. In such processes, the yarn is commonly passed through a false-twisting device, such as a twisting spindle or torque jet, such that twist backs up along the yarn prior to the device where it comes in contact with a heated metal plate which heat-sets the twisted

yarn, the yarn upon passing through the twisting device is twisted equally in the opposite direction without the application of heat such that the cooled, untwisted yarn has torsional energy stored within it.

The preferred false-twist texturing process of this invention provides false-twist textured yarns having an outstanding combination of properties superior to any false-twist textured yarns known heretofore. The products are characterized by having a Crimp Index, as defined herein, greater than 30, preferably 35, and a Crystallinity Index greater than about 50. Prior to the discovery of this invention, continuously false-twisted, textured yarns having this high degree of crimp were unknown.

As previously stated, the feed yarn filament Crystallinity Index must be less than about 20 and preferably 15. This, of course, must be accomplished without sacrificing other desirable filament tensile properties such as tenacity and toughness. Filaments meeting this requirement can be prepared by conventional melt-spinning and drawing techniques although special care is required. The development of crystallinity during spinning and drawing can be minimized by raising the spinning temperature or by delayed quenching while increasing the draw ratio, for example by spinning into a heated inert atmosphere such that the filaments are permitted to attenuate more completely during spinning before cooling. Melt spinning at temperatures from about 300-335° C. into an enclosed steam atmosphere immediately below the face of the spinneret maintained at a temperature of about 150-250° C. is quite effective in helping to obtain the desired degree of crystallinity.

Texturing of filaments and yarns by this invention involves normal processing considerations. For example in the preferred false-twist texturing process, the twist level employed 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 about 50 t.p.i. (19.7 per cm.) are preferred. Once twist level has been specified the remaining texturing variables such as feed rate and temperature are adjusted for optimum Crimp Index. Yarn feed rate controls pre-spindle tension in the process and also post-spindle tension as well. If post-spindle tension is too high this reduces the resulting Crimp Index because of pullout of the crimp. If tensions are too low, again Crimp Index is lowered and tight spots can be formed due to non-uniform twist slippage around the spindle pin. For each combination of twist and feed rate there is a temperature at which Crimp Index is at a maximum and post-spindle tension is at a minimum. An abrupt increase in tension as temperature of the contacted heating surface is increased is an indication of lubrication failure of the texturing finish on the yarn. The temperature at which this occurs varies with type and level of finish and with spindle tension. The higher the spindle tension, the lower the temperature at which such failure occurs. In general, once the twist level is established for yarn having a given denier per filament, the approximate best value for other deniers can be estimated by using the appropriate twist multiplier.

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 overlaid 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.

*Relative viscosity (RV)* as used herein is determined on a 6.166% by weight solution of PACM-12 in a solvent consisting of 50% by weight of 98-100% formic acid and 50% freshly distilled phenol. The solvent mixture has a

density of  $1.126 \pm 0.001$  grams per  $\text{cm}^3$  at  $25^\circ \text{C}$ . The procedure is defined in U.S. Pat. No. 2,385,890. The effluxing time of the polymer solution is then determined in a viscometer maintained at  $25 \pm 0.05^\circ \text{C}$ . Relative viscosity is the flow time of the polymer solution divided by the flow time of the solvent alone measured under the same conditions.

Crystallinity as discussed herein is determined by measurements made on a wide angle X-ray diffraction pattern. A sensitive X-ray measurement of crystallinity is obtained by making use of the intense diffraction spots on the meridian of the diffraction pattern. Filaments of 70% t.t. PACM-12 which have been spun under low tension and drawn at a temperature of less than about  $180^\circ \text{C}$ . have relatively little lateral order and show amorphous diffraction on the equator in a Bragg X-ray film crystal diagram (FIG. 1). They possess longitudinal order as shown by a single strong meridional reflection (II) corresponding to the second layer line of the crystals. Upon heating the filaments while free to relax, changes occur in the equatorial diffraction accompanied by the appearance of the first layer meridional spot (I) almost directly underneath the beam spot. As crystallinity continues to develop on further heating, changes occur in the relative intensity (optical density) of the first and second meridional spots, the first (I) increasing in intensity at the expense of the second (II). Of these two meridional diffraction spots, (I) is a  $2\theta$  position of  $3.88^\circ$  and exhibits a low intensity when the crystallinity is low; (II) is at a  $2\theta$  position of  $7.85^\circ$  and is more intense than (I) when the crystallinity is low. When the crystallinity of the fiber is increased the intensity of (I) increases and (II) decreases. It is found that obtaining the ratio of these intensities (I/II) as determined by optical density on the X-ray diffraction pattern provides a very reliable index of the relative crystallinity of the fiber called *Crystallinity Index* which is determined directly from FIG. 2 using the value calculated for the peak intensity or optical density ratio. This index, although not a quantitative value per se, is a convenient means of measuring relative degrees of crystallinity in the fiber. The index is based on a scale as shown in FIG. 2. This index uses the basic assumption that the diffraction intensity in spot (II) converts to the intensity of spot (I) with increasing crystallinity. This means that at an index of 50 the diffractions (I) and (II) are of equal intensity. Limits of 0 and 100 are for the situations in which there is no measurable intensity of the diffractions (I) and (II), respectively. The values of the peak intensity are read directly from the optical density values measured by a microphotometer after subtracting the base line background value. The Crystallinity Index X-ray patterns are obtained using a flat plate vacuum camera to eliminate air scattering, nickel filtered copper X-rays at 40 k.v.p. and 20 milliamperes current, a General Electric XRD-5 X-ray unit with a CA-8 X-ray tube, pinhole collimation with a separation of 7 cm., an outside pinhole diameter of 0.025 inch (0.64 mm.) an inside pinhole diameter of 0.02 in. (0.51 mm.), a sample thickness no greater than about 0.02 in. (0.51 mm.), a sample to film distance of 7.5 cm. and Kodak<sup>1</sup> No-Screen film or film providing equivalent contrast. Kodak No-Screen film is developed for 3 minutes at  $20^\circ \text{C}$ . using Kodak X-ray Developer as recommended by the manufacturer. A microphotometer instrument is used to convert the blackening on the X-ray film to optical density values as shown in FIG. 1. The values of the peak intensity are read directly from the optical density values produced by the microphotometer, after subtracting the base line background value. Care must be exercised to obtain optimum exposure levels, especially at low index values below 20. For these low values the inner diffraction (I) should have a minimum optical density of at least 0.05 above

background. The outer diffraction (II) should have an optical density below 1.0 and in no case should it exceed 1.5. With these limits it is possible to measure a Crystallinity Index as low as 3 and have a precision of  $\pm 1$ .

*Crimp Index* is a measure of the amount of yarn elongation available due to crimp. The values reported herein were determined on a skin of bailed off yarn within 24 hours after texturing. The measured crimp index of false-twist textured yarn decreases with time at a known and reproducible rate. For example, after seven days, the crimp index decreases to about 93% of the level observed within one day of texturing and the level further decreases to about 85% then 77% in 14 and 21 days, respectively. The crimp index measured after 21 days changes very little with time, remaining at about 77–78% of the initial level. A 5,000 denier skein is prepared by winding under a tension of 0.1 gram per denier, (based on textured yarn denier under 0.1 g.p.d. tension). The textured skein is conditioned by hanging a 25 gm. metal weight on the skein and suspending the skein with the weight attached in boiling water for 15 minutes. The skein is permitted to air dry while under the same load. The skein length is then measured under the same 25 gram load (crimped length,  $L_c$ ) and then under a 500 gram load (extended length,  $L_E$ ). Percent Crimp Index is

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

#### EXAMPLE I

This example demonstrates the critical relationship between yarn crystallinity and crimp formed during a false-twist texturing process.

Filaments are melt-spun in a conventional manner from a PACM-12 polymer having a relative viscosity of 54 and containing 70% of the trans-trans PACM isomer. A 34 hole spinneret is used wherein the holes have a diameter of 15 mils (0.38 mm.). The temperature of the spinneret block is  $330^\circ \text{C}$ . and the filaments are wound up after quenching at a speed of 750 y.p.m. (685 meters/min.). The yarn is then drawn to a draw ratio of  $2.4\times$  in a conventional manner using a hot pin at  $90^\circ \text{C}$ . and a hot shoe at  $180^\circ \text{C}$ . The drawn yarn has an average denier of 74, a tenacity of 5.0 g.p.d. and an elongation of 19%. It is found to have a Crystallinity Index of 14. The yarn is false-twist textured in a conventional manner on a Model 552 false-twist texturing machine manufactured by the Leesona Corp., Warwick, R.I. The machine is operated so as to give about 80 t.p.i. at a spindle speed of 148,000 r.p.m. Optimum texturing conditions are found to be a heater temperature of  $226^\circ \text{C}$ ., with a yarn overfeed of  $+3.8\%$ . The resulting textured yarn is found to have a Crimp Index of 39.6% and a Crystallinity Index of 57.

Similar texturing response is obtained with feed yarns having low Crystallinity Indexes when the spindle of a conventional Model 553 false-twist texturing machine is replaced by a torque jet for twisting the yarn. The jet is operated under an air pressure of 70 p.s.i. with a yarn speed of 80 y.p.m., which is equivalent to the twisting conditions of 80 t.p.i., when the spindle is used at 240,000 r.p.m. Under these conditions, a 65 relative viscosity, 65 denier-34 filament yarn is false-twist textured and attains a 32.7% Crimp Index when a heater temperature of  $232^\circ \text{C}$ . is used.

When attempts are made to false-twist texture a yarn in the same manner comprised of PACM-12 having a relative viscosity of 77, containing 70% trans-trans PACM-isomer and having a Crystallinity Index of 26, a maximum Crimp Index of 20.7% is obtained. The 34-filament yarn denier averages 64.8 and yarn properties average 4.7 g.p.d. with an elongation of 31.5%. The yarn is processed on a Model 553 machine and optimum conditions found to give the above maximum Crimp Index are  $222^\circ \text{C}$ . for the heater temperature and an overfeed of  $+4\%$  to the heater running at a spindle speed of

<sup>1</sup> Registered trademark.

240,000 r.p.m. The yarn is prepared in a conventional manner using a coupled spin drawing process with a spinneret having 9 ml. (0.23 mm.) diameter holes, a spinneret block temperature of 310° C. and drawn in a coupled spin-draw operation in two steps with snubbing in the first stage followed by heated second stage draw rolls maintained at a temperature of 155° C. The yarn is spun at a speed of 3,100 y.p.m. with a first stage draw roll speed of 3,130 y.p.m., a second stage draw roll speed of 3,575 y.p.m. and wound up at a speed of 3,403 y.p.m.

Yarn of about the same count and denier prepared in a similar manner by a coupled spin-draw process from a PACB-12 polymer of the same isomer composition and a relative viscosity of 73 is found to have a Crystallinity Index of 21. Again operating at a speed to give about 80 t.p.i., optimum texturing conditions on a Model 553 machine operating at 245,000 r.p.m. spindle speed, heater plate at 222° C. with a plus 3.0% overfeed gives a maximum Crimp Index of 24.7%. The same yarn on a Model 552 machine operating at 145,000 r.p.m. spindle speed at the same temperature and a +4.3 yarn overfeed gives an optimum Crimp Index of 25.9%. The textured yarn has a Crystallinity Index of 63. This shows that the subject yarns give essentially equivalent performance on both machines which differ primarily only in their operating speed. In both cases, attempts to adjust operating conditions to attain the higher Crimp Index i.e. 39.6% shown above for the yarn initially having a Crystallinity Index below 20, are unsuccessful.

For comparison, a commercially available texturing feed yarn of poly(hexamethylene adipamide) having a tenacity of about 4.4 g.p.d. and 2 d.p.f. is found to give a Crimp Index of only about 9-11% upon false-twist texturing in the same manner. A commercially available texturing feed yarn of poly(ethylene terephthalate) having a d.p.f. of 2 and a tenacity of 4.1 g.p.d. is found capable of giving a Crimp Index of only about 13-16% in the same process. Thus, the outstanding texturing performance and resulting products from the process of this invention are evident.

#### EXAMPLE II

A yarn is prepared in a conventional manner by melt-spinning and drawing a PACM-12 polymer having a relative viscosity of 46.6 and containing 90% of the trans-trans PACM-isomer. The yarn contains 34 filaments and has a total denier of 88.9. It has a tenacity of 3.6 g.p.d., elongation of 12.1% and an initial modulus of 35.6. It has a Crystallinity Index of 5. It is false-twist textured on a commercial Model 552 machine at 80 t.p.i., with a spindle speed of 140,000 r.p.m., 0% overfeed over a range of heater temperatures from 121° C. to 260° C. The highest Crimp Index obtained without objectionable tight spotting is 50%, obtained at a temperature of 228° C. The textured yarn has a Crystallinity Index of 65.

#### EXAMPLE III

This example demonstrates that the outstanding performances of PACM-12 yarns in this invention is not a common property of PACM-based polycarbonamides in general, e.g. PACM-10, derived from PACM and sebacic acid.

A 34-filament yarn is prepared by a coupled melt-spinning and drawing process from a polymer of PACM containing 55% of the trans-trans isomer and sebacic acid. The polymer has a molecular weight, as calculated from end-group analysis in a conventional manner, of about 15,000. The yarn is drawn 3X in two-stages using a heated pin (125° C.) followed by drawing around a heated pipe, 160° C. at the input, 170° C. center and 190° C. at the take-off point. The drawn yarn has a Crystallinity Index of about 4, a tenacity of 3.9 g.p.d. and an elongation of 38%. Attempts are made to texture the yarn on a Leeson Model 552 false-twist texturing machine operating at 80 t.p.i., 140,000 r.p.m. spindle speed and +3.0%

yarn overfeed to the heater. The heater temperature is varied to determine conditions under which acceptable yarns of maximum Crimp Index are produced. Above 177° C. the yarn tends to fuse. At 177° C., the temperature at which maximum Crimp Index at 80 t.p.i. is obtained, the resulting Crimp Index is only 5.2% and the textured yarn Crystallinity Index is only about 5.

#### EXAMPLE IV

A 15 denier-3 filament hosiery yarn is prepared by spinning an 80 relative viscosity PACM-12 polymer (70% tt isomer) at 330° C. from a steam blanketed spinneret, quenching and drawing the filaments immediately without intermediate packaging at a draw ratio of 1.5X, applied in two stages. The first stage draw rolls are unheated; the second stage draw rolls are in a hot chest wherein the yarn is annealed at 170° C. This yarn has a tenacity of 4.3 g.p.d., a break elongation of 25.5%, and a crystallinity index so low that it is not measurable (less than 3). This yarn is false-twist textured on a Model 553 machine at a 240,000 r.p.m. spindle speed, producing (in this yarn) a twist of 155 turns per inch. A crimp index of 42.3% is obtained at a heater temperature of 210° C., 0% heater overfeed.

#### EXAMPLE V

A 16.4 denier, 3 filament hosiery yarn is produced as in Example IV, using a 1.57X draw ratio. The yarn has a relative viscosity of 68, 4.2 g.p.d. tenacity, an elongation of 38.0% and a crystallinity index of 9. It is textured on a Model 553 machine at 140 t.p.i. applied twist, 0% lower overfeed, 5% upper overfeed, 240,000 r.p.m. spindle speed.

The textured yarn has a crimp index of 43% and a Crystallinity Index of 53.

False-twisted, textured, stretch yarns produced by the process of this invention may be subsequently heat-set to produce a bulky, non-stretch yarn by known methods. The resulting stabilized, bulked yarn retains a higher Crimp Index than do previously known yarns. The heat-setting operation may be performed as a separate step, for example by a known method of inducing a small amount of true-twist 2-3 t.p.i. and passing the textured yarn over a heater plate, or it may be done continuously by heat-setting immediately following the false-twisting operation by known methods.

The process of this invention may be applied to yarns containing filaments of any textile denier and cross-section. Normally, heavier filament deniers result in the retention of a higher Crimp Index, all else remaining the same.

For this reason, the product of this invention is especially useful in the preparation of high d.p.f. hosiery yarns, such as 15-3, 15-2, 20-4, 20-3 and the like. Modified or non-round cross-sections, for example trilobal, affect the twisting and bending properties of the filaments and consequently their texturing and textured properties. Thus, the observed crimp index will depend significantly on whether the filament cross-section is round or modified, e.g., trilobal, since the filaments follow conventional mechanical formulae describing the behavior of springs. As an example, at the same denier per filament, a round filament yarn textured so as to have a crimp index of 40 will only have a crimp index of 25 when the cross-section is trilobal. For yarns of corresponding cross-section, of course, the yarn of the instant invention will have superior texturing response.

The process of this invention may be applied to mixed filament yarns containing, in addition to the filaments specified herein, filaments of differing polymer composition or properties having different response under the texturing conditions.

What is claimed is:

1. A process for texturing a feed yarn comprising a plurality of continuous substantially straight filaments

constituted at least 50% by weight of repeating polymeric units of bis(4-cyclohexylene) methane dodecanediamide, at least 45% of the bis(4-cyclohexylene) methane portion of said units being in the trans-trans isomer form, said filaments having a Crystallinity Index of less than 20 and a relative viscosity greater than 45, said process comprising the steps of:

- (a) mechanically distorting said filaments from the straight configuration by external forces;
- (b) heating said filaments in the distorted configuration by subjecting them to a temperature of at least about 160° C. until the Crystallinity Index of the filaments increases to at least about 40; and
- (c) cooling the filaments.

2. The process of claim 1 wherein the filaments of said feed yarn are constituted essentially of repeating polymeric units of bis(4-cyclohexylene) methane dodecanediamide.

3. The process of claim 1 wherein the filaments of said feed yarn have a Crystallinity Index in the range of from less than 20 to greater than 5.

4. A process for texturing a feed yarn comprising a plurality of continuous substantially straight filaments constituted at least 50% by weight of repeating polymeric units of bis(4-cyclohexylene) methane dodecanediamide, at least 60% of the bis(4-cyclohexylene) methane portion of said units being in the trans-trans isomer form, said filaments having a Crystallinity Index of less than 20 and a relative viscosity greater than 45, said process comprising the steps of:

- (a) twisting the filaments to a twist level of greater than 50 turns per inch;
- (b) heating the twisted filaments by subjecting them to a temperature of from 200° C. to 238° C. until the Crystallinity Index of the filaments increases to at least about 50; and
- (c) continuously cooling while simultaneously untwisting said filaments.

5. The process of claim 4 wherein the filaments of said feed yarn are constituted essentially of repeating polymeric units of bis(4-cyclohexylene) methane dodecanediamide.

6. The process of claim 4 wherein the filaments of said feed yarn have a Crystallinity Index in the range of from less than 20 to greater than 5.

7. The process of claim 4 wherein the filaments of said feed yarn have a Crystallinity Index of about 15.

8. A mechanically bulked yarn comprising; a plurality of continuous filaments constituted at least 50% by

weight of repeating polymeric units of bis(4-cyclohexylene) methane dodecanediamide, at least 45% of the bis(4-cyclohexylene) methane portion of said units being in the trans-trans isomer form, said filaments having a relative viscosity greater than 45, said yarn being characterized as to elongation due to crimp by a Crimp Index greater than 30%, said yarn being further characterized as to relative crystallinity by a Crystallinity Index of at least about 40.

9. A yarn according to claim 8 wherein the filaments are constituted essentially of repeating polymeric units of bis(4-cyclohexylene) methane dodecanediamide.

10. A yarn according to claim 8 wherein from at least 45-100% of the bis(4-cyclohexylene) methane portion of said units are in the trans-trans isomer form.

11. A yarn according to claim 8, said yarn having a denier per filament of from about 1 to about 8.

12. A false-twist textured yarn comprising; a plurality of continuous filaments constituted at least 50% by weight of repeating polymeric units of bis(4-cyclohexylene) methane dodecanediamide, at least 60% of the bis(4-cyclohexylene) methane portion of said units being in the trans-trans isomer form, said filaments having a relative viscosity greater than 45, said yarn being characterized as to elongation due to crimp by a Crimp Index greater than 30%, said yarn being further characterized as to relative crystallinity by a Crystallinity Index of at least about 50.

13. A yarn according to claim 12 wherein the filaments are constituted essentially of repeating polymeric units of bis(4-cyclohexylene) methane dodecanediamide.

14. A yarn according to claim 12, said yarn having a denier per filament of from about 1 to about 8.

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