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[54] **METHOD OF MAKING LATENTLY CRIMPABLE YARN FROM POLYBLEND AND PRODUCT**
6 Claims, 1 Drawing Fig.

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[56] **References Cited**

UNITED STATES PATENTS

3,038,235	6/1962	Zimmermen	161/177 X
3,336,174	8/1967	Dyer et al.	28/1 F UX
3,352,778	11/1967	Brink et al.	161/173 X
3,424,358	1/1969	Robinson et al.	28/1 X
3,505,164	4/1970	Oppenlander	161/177 X
3,506,535	4/1970	Prevorsek	161/177

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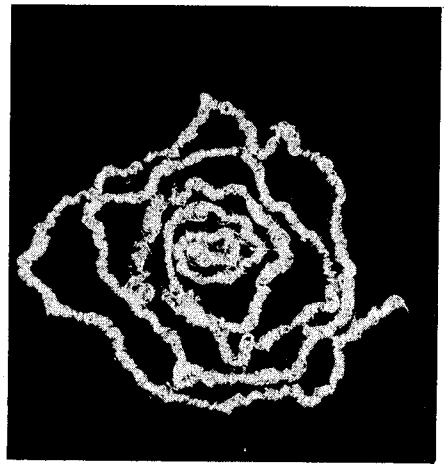
ABSTRACT: A multifilament fine denier latently crimpable yarn from a polymeric blend of incompatible thermoplastic polymers such as a polycaproamide/polyethylene terephthalate and/or polypropylene blend; and process of producing it. The process involves subjecting a monofil, film or tape of the polymer blend, in semiamorphous state, to a rolling pressure applied progressively down the length against one crosswise dimension, and then applying a transverse force gradient preferably created by impelling the structure in a high velocity gas stream against a deflecting surface. The crimp is preferably developed by exposing the split yarn under low tension to hot gas or vapor.



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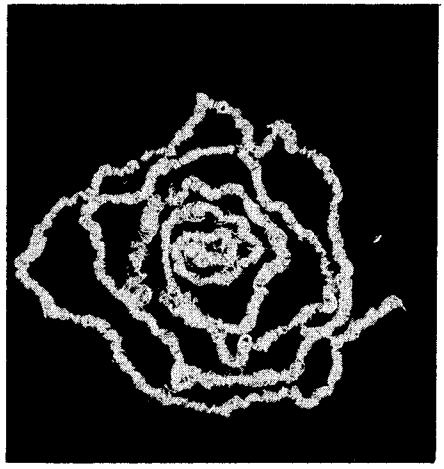

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METHOD OF MAKING LATENTLY CRIMPABLE YARN FROM POLYBLEND AND PRODUCT

BACKGROUND OF THE INVENTION

This invention relates to production of latently crimpable synthetic filaments, especially in the form of yarns, and to the latently crimpable and the crimped filaments obtained. The process of the invention produces yarns composed of fine filaments or fibers averaging not over four denier in size, which yarns can display free fiber ends but are nevertheless sufficiently strong and coherent to permit further processing. These yarn products of the invention show latent crimpability; i.e. upon exposure to conditions releasing internal strains, such as upon exposure to conditions releasing internal strains, such as heat or swelling agent, the filamentary products obtained by this process assume crimps which impart to the yarn bulkiness, covering power, and insulating properties. The resulting yarn confers desirable feel, appearance, and comfort in fabrics made therefrom.

A number of methods have been proposed in the art to make synthetic yarns latently crimpable. Among such methods is the application of differential heating transversely of the yarn, e.g. by use of differentially heated nip rolls (U.S. Pat. No. 3,166,822 of Jan. 26, 1965 to Starkle). Another procedure effecting differential heating and/or differential straining transversely of the yarn, to make the yarn latently crimpable, is to draw the yarn over a narrow edge at a sharp angle ("edge crimping").

According to U.S. Pat. No. 3,398,441 of Aug. 27, 1968 to Adachi et al., latently crimpable fibers are produced from a thin film or tape of fiber-forming polymer by heating and stretching the film or tape, then passing it over an "edge-crimping" blade or wire; then splitting it into fibrous material, e.g. by passing it across a bar file, via one pair of nip rolls to forward the film to the file and another like pair to take up the resulting fibrous material. Suitable polymeric materials include materials such as polyethylene, polypropylene, polyamides, polyesters, polyacrylonitrile and the like. The individual fibers produced from the homogeneous phase polymer compositions of this U.S. Pat. No. 3,398,441 are of mean size 7–15 denier. To achieve desirable soft feel, much finer individual fibers must be produced. Such fine fibers can be produced by splitting, under controlled conditions, blends of incompatible polymers ("polyblends") wherein one or more polymer species is in dispersed phase in a continuous phase or matrix of another polymer species. Such polyblends are disclosed in British Pat. No. 930,074 of Union Carbide Corp., published July 3, 1963, as well as methods of splitting structures thereof, e.g. flexing over a sharp edge.

With the polymer compositions with which this invention is concerned, namely, with the incompatible polymer blends which are to be split into fine fibers having an average size of not over four denier the "edge-crimping" method of U.S. Pat. No. 3,398,441 and British Pat. No. 930,074 cannot be applied as a practical matter to obtain fine fibers with high latent crimpability. The degree of latent crimpability achieved by the "edge" method is low, at moderate pressure of the fiber against the crimping edge. When the pressure is increased, films prepared from polyblends do not have sufficient strength to withstand the resulting stresses. Thus, breakage poses a severe problem in the preparation of fine denier yarns having a high level of crimp by such edge-crimping procedure. Moreover the frequency of breakage increases if one attempts to achieve higher linear speeds of the film throughput. Consequently, the method is limited to low production rates, at least when processing polyblends as used in the herein-described operations.

Another obstacle in achieving high production rates using edge crimping is that the degree of crimping achieved by this method decreases rapidly with increasing linear speed of film.

Abrasion is another problem particularly noticeable when polyblend is used for films which are rubbed against an edge.

Under such conditions the losses in weight may exceed several percent with consequent increase in cost of production. In addition the abraded material tends to accumulate at the edge which may cause filament breakage and nonuniformity in the final product. In a known method of splitting a structure such as a film or tape to form fine fibers, the structure is subjected to the action of an air jet. The present invention is advantageously operated using an air jet to effect splitting. This invention is operable with structures such as thin films or tapes and also with round or near round filaments (e.g. monofils) and thick tapes.

SUMMARY OF THE INVENTION

Advantages provided by this invention include high processing speeds and minimal abrasion waste. Because there is no necessity of putting the treated material under tension, it is possible to treat by this method even very weak materials such as molecularly unoriented structures from blends of incompatible polymers. Such structures often exhibit excellent splitting characteristics.

In accordance with this invention, an asymmetric strain is inducted in an elongated structure composed of a blend of incompatible thermoplastic polymers. More particularly the polymers are fusible and the blend is extruded from the melt in the form of an elongated structure, which is solidified preferably by quenching in a liquid bath. When the polymers or one of them is capable of molecular orientation, the resulting structure is usually stretched to produce high molecular orientation. During the stretching, exposure to elevated temperature is such that at least one of the polymer components retains more than its normal equilibrium amorphous content.

A rolling pressure is then applied progressively down the length against one crosswise dimension of the solid elongated structure, which is maintained in its semiamorphous state, i.e. at less than full crystallinity, by maintaining its temperature below the glass transition temperature of at least one component thereof. (As is known in the plastics art, the glass transition temperature is a second order transition temperature at which an abrupt change occurs in a property such as bending modulus or tensile modulus.) This pressure serves to reduce one crosswise dimension of the structure by at least 30 percent, suitably about 50–80 percent.

Next the structure is subjected to a transverse force gradient as by twisting, flexing, rubbing, or tearing, serving to split the structure longitudinally into fine fibers. A preferred means of creating this transverse force gradient is by forwarding the elongated structure, which has been strained by rolling pressure, in a high velocity stream of air by which the structure is impelled against a deflecting surface. The structure splits into a multitude of filaments or fibers which show latent crimpability, i.e. capability to crimp upon release of strain therein, for example by heating while the yarn is under low tension not above 0.1 gram per denier. Release of strain by exposing the yarn in relaxed, tensionless state to hot air is a particularly convenient method, e.g. by conveying the yarn down a heated tube in a stream of heated air.

The crimped yarn of this invention, thus obtained, consists of a multitude of fine fibers having varying denier, with average denier per fiber not over four. Thereby desirable softness of feel is assured. Average denier per fiber as low as 0.4 can be obtained using compositions particularly well adapted to splitting, such as 50/25/25 parts by weight of polycaproamide/polyethylene terephthalate/polypropylene. The crimp is irregular as seen in the accompanying drawing, and can be varied in intensity by varying the processing conditions discussed below and the composition of the polyblend. The crimp index, i.e. (straightened length—tensionless crimped length)/(tensionless crimped length), can be adjusted from as low as 20 up to several hundred, e.g. from 20 up to 300, expressed in percent.

Specifically, the rolling pressure can be applied to a monofil or tape by means of two rollers which are set e.g. at constant

clearance or constant pressure, or at clearance maintained constant unless pressure falls outside a predetermined range.

For purposes of illustration, one can consider the conditions of plastic strain in a cylindrical monofilament passing between two rollers, when the gap between the rollers is smaller than the diameter of the filament. The central portion of the filament will experience strong compressive strain, while the side portions will experience none. All portions of the filament will thus be exposed to a differential strain field. After Splitting, the fibers in the resulting yarn will then have latent crimpability due to the built-in asymmetrical strains, which when released by heating will produce a crimp provided the release of strain occurs while the yarn is under low tension allowing it to take a crimped form. Such tension is not above 0.1 gram per denier.

The accompanying drawing shows the appearance of crimped yarn of this invention as seen in a photomicrograph.

PREFERRED EMBODIMENTS

One special feature of the present invention is the latent crimpability of the fibers, whereby a mechanical deformation followed by a heating step results in a spontaneous increase in the extent of deformation. The molecular mechanism responsible for this effect is not completely understood. It is believed, however, that it can be at least in part attributed to the differential crystallization characteristics in different polymers composing the fibers, or in different portions of a single polymer within a fiber. When the split fiber is heated, these differences introduce asymmetrical shrinkages or extensions which cause the fibers to crimp. A process of crystallization most likely accounts for the phenomenon as can be demonstrated by annealing the unsplit monofil. Such an annealed monofil, when subjected to the sequence of straining, splitting and heating steps previously described, will give yarn crimped to a much lesser extent than a monofil and yarn in which crystallization has been inhibited up to the time of exposure to the temperature at which the crimp is developed. Accordingly the maximum crimp is obtained when the monofil is quenched in a liquid bath, at say about room temperature (15–25° C.), as it emerges from the spinning die and thereafter is maintained at the lowest temperature consistent with good performance in other processing steps such as molecular orientation by stretching, and rolling to impose strain. MOreover, splitting and crimping should be carried out with minimum delay after extrusion, since long aging has the same restrictive effect on the development of crimping as does annealing.

The degree of permanent reduction in thickness (for convenience herein called "flattening") of the elongated structure can vary between wide limits. The process of this invention will give crimped yarn when the gap between rollers is such that the ratio of gap to monofil diameter is as high as 0.8. Where the material is fed to the rollers in the form of a slit film or tape, the permanent reduction in thickness sufficient to produce crimp can be as little as 10 percent. These limits, however, are not fixed but are subject to a further condition, namely, that the flattened structure should possess a sufficiently high surface to volume ratio to undergo splitting in the next step of the process. A suitably high ratio is particularly important when the splitting is by use of a fluid jet.

Adjusting the gap between the rollers exercises a fine control on the number of fibers into which the structure is divided when splitting is accomplished using an air jet. Varying the ratio of gap to monofil diameter from 0.8 to 0.2 provides, from the same monofil, split yarns with average denier per fiber ranging from 20 to 0.4. Over the whole range, high degree of crimp was developed by subjecting the split yarns to the action of a stream of hot air. The lower ratios should be used to obtain fine denier filaments in accordance with this invention, viz. not over 0.7, suitably about 0.5 to 0.2. Temperatures of the rolls, as above noted, should be below the glass transition temperature of at least one of the polymer components of the monofil; unheated rolls are suitable.

The air jet referred to above as being used for splitting is essentially a means of impelling the elongated structure, strained by rolling pressure as above described, against a deflecting surface with high velocity. Suitably the jet is a nozzle with a central channel through which air is forced under pressure such as 10–100 p.s.i.g. thus imparting high velocity. The elongated structure, e.g. flattened monofil, is introduced into the air stream, e.g. from one side, and is carried thereby through a tubular or like guide or passage and against a surface or obstacle at or just beyond the passage. The monofil is abruptly deflected by the surface and thereupon splits into numerous fibers; and is withdrawn. A suitable surface is, for example, a cylindrical surface from which the split yarn is deflected. The resulting yarn product is made up of fine fibers having latent crimpability.

Various means of promoting crystallization will serve the purpose of developing crimp. Among these may be included treatment with swelling solvents, heating in a current of hot gas, heating in a hot liquid, etc. The term crystallization is here meant to include any process in which either the amount or the type of crystallinity is altered. The first kind of crystallization simply involves a conversion of noncrystalline or amorphous to crystalline material. The second kind can involve changes in the crystal structure from one conformation to another. For example, it has been shown that nylon 6 (i.e. fiber-forming polycaproamide) can exist in three distinguishable crystalline forms beside the amorphous form, and that by suitable treatment the less stable forms can be transformed to the more stable. Yet another kind of change in crystallinity may involve increases in order or in fold length. These two types of changes can occur within one crystalline form. The first is manifested by the increased sharpness of the reflected pattern in X-ray diffraction experiments and represents a move toward greater uniformity in crystalline spacings. The second, more difficult to detect, can be identified by certain changes in the absorption of infrared radiation by the material, and is a process whereby the polymeric chains, which in polymer crystals have been shown to exist in a folded configuration, move so as to increase the length of polymer chain between folds. This has the effect of increasing the size of the crystals in the direction of the polymer chains.

By means of the process described above, soft bulky yarns can be produced having many free fiber ends and frequent fiber entanglement so as to form a kind of network when spread out. Consequently the yarns have substantial tensile strength even without being twisted.

The crimp that can be developed in these materials can be varied from a low level comparable to that found in wool to a very tight, coiled conformation which makes the yarn suitable for stretch-type apparel. Other uses in which yarns of this invention can be employed are in draperies, upholstery, carpet, insulation, and linenlike textiles.

The following examples set forth and illustrate the best mode now contemplated for carrying out the invention and provide specific embodiments of the invention. Parts are by weight. Reduced viscosity is given by: $(n-n_o)/n_oC$ where

n = viscosity of polymer solution

n_o = viscosity of pure solvent

C = concentration in grams of polymer per deciliter of solvent.

EXAMPLE I

A. A dry blend of 70 parts of polycaproamide having a number average molecular weight of 27,000 and 30 parts of polyethylene terephthalate having a reduced viscosity in metacresol of 0.27 deciliter/g. was extruded as a monofil at a temperature of 277° C. through a die 0.030 inch in diameter into a quench path. The extrudate was attenuated in the molten state by being pulled down around a roll rotating at greater peripheral speed than the average linear speed of the molten stream flowing from the die orifice, to give a monofil 0.012 inch in diameter. The quench bath contained water at 17° C.

and was held 1 inch below the die. The monofil was then stretched fourfold at a temperature of 175° C. thus molecularly orienting it and reducing its diameter to about 0.006 inch. It was split by being passed at 500 f.p.m. between rollers separated by a 0.003-inch gap, then impelled against a cylindrical surface by use of an air jet. The resultant yarn consisted of an average of 200 fine fibers, of average size about one denier per fiber. The yarn was transported down a heated tube under zero tension in a current of hot air at 150° C. A crimp was instantly developed, characterized by a 2.5-fold increase in length when the tensionless crimped yarn was pulled out straight by applying a tension of 0.1 gram per denier, i.e. the crimp index was 250.

B. The same stretched monofil of this example I when pulled over an edge at linear speed substantially exceeding 50 f.p.m. broke frequently. A crimped structure produced therefrom over such edge at a speed less than 50 f.p.m. showed lower bulkiness and was of coarse texture as compared to the yarn made by the rolling procedure of (A) above.

EXAMPLE II

A dry blend of 40 parts of polycaproamide having a number of average molecular weight of 27,000, 30 parts of polyethylene terephthalate having a reduced viscosity in *m*-cresol of 0.20 deciliter/g. and 30 parts of polypropylene having a number average mol. wt. of 208,000 was extruded as a monofil at a temperature of 277° C. through a die 0.030 inch in diameter. The extrudate was pulled down faster than it flowed from the die orifice so that the resulting monofil was 0.010 inch in diameter. The quench bath contained water at 17° C. and was held one-half inch below the die. The monofil was then stretched 3.5-fold at a temperature of 160° C. The diameter of the monofil, thus molecularly oriented, was about 0.005 inch. The monofil was split by being passed between a set of rollers separated by 0.002-inch gap and then through an air jet device. The resultant yarn consisted of an average of 250 fine fibers, of average size about 0.5 denier per fiber. Crimp was developed by heating as in example I, characterized by a 2.75-fold increase in length when the tensionless crimped yarn was pulled straight with a tension of 0.1 g./denier; i.e. the crimp index was 275.

Attempts to produce crimp by continuously pulling over an edge resulted in filament breakage even at speeds as low as 40 f.p.m. At higher speeds, fine dust particles started collecting on the edge which also contibuted to higher breakage rates of the filament.

EXAMPLE III

A dry blend of 35 parts of polycaproamide having a number average molecular weight of 19,000 and 65 parts of polypropylene having a number average molecular weight of 295,000 was extruded as a monofil at a temperature of 271° C. through a die 0.030 inch in diameter into a quench bath. The extrudate was drawn down in the melt as described in examples I and II to obtain a 0.021-inch diameter monofil. The quench bath was water at 17° C. held one-half inch below the die. The monofil was stretched fourfold at 160° C. to a molecularly oriented monofil of diameter about 0.010 inch. It was split by being passed between a set of rollers separated by 0.0025-inch gap and through the air jet device as described in example I. The resultant split yarn consisted of an average of 175 fine fibers of average size about three denier per fiber. Crimp was developed as in example I. The crimped yarn when straightened under a tension of 0.1 gram per denier showed a 2.6-fold increase in length, i.e. the crimp index was 260.

The invention claimed is:

1. An improved multifilament crimped yarn composed of a polymeric blend of incompatible thermoplastic polymers wherein one or more polymer species is in dispersed phase in a continuous phase of another polymer species; said yarn comprising individual filament fineness such that the average denier per filament or fiber is not over four and having latently developed crimpability of the filaments or fibers which have been developed by heat to produce a crimp index of at least 20.

2. Multifilament yarn of claim 1 wherein the latent crimpability produces a crimp index in the range from 20 up to 300.

3. A multifilament crimped yarn composed of a polymeric blend of incompatible thermoplastic polymers wherein one or more polymer species is in dispersed phase in a continuous phase of another polymer species; said yarn having the improvement comprising individual filament fineness such that the average denier per filament or fiber is not over four, combined with crimp at a crimp index of at least 20.

4. A process for producing latently crimpable yarn from a splittable, elongated structure composed of a polymeric blend of incompatible thermoplastic polymers wherein one or more polymer species is in dispersed phase in a continuous phase of another polymer species; wherein the improvement comprises producing fine fibers having latent crimpability by (1) restricting the crystallization of said slittable, elongated structure whereby it is in a semiamorphous state; (2) subjecting said structure to rolling pressure applied progressively down the length against one crosswise dimension while maintaining the semiamorphous state by maintaining the temperature of the structure below the glass transition temperature of at least one polymeric component thereof; and (3) subjecting the structure in semiamorphous state to a transverse force gradient serving to split the structure longitudinally into fine fibers.

5. Process of claim 4 wherein the transverse force gradient is created by impelling the elongated structure, strained by rolling pressure, in a high velocity stream of gas or vapor against a deflecting surface.

6. Process of claim 5 with the additional feature that the multifilament split yarn, obtained by said process in semiamorphous state, is exposed to a current of hot gas or vapor while under low tension not above 0.1 gram per denier, whereby crimp is developed in said yarn at a crimp index within the range between 20 and 300.