METHOD FOR PRODUCING CRIMPED FIBERS

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Filed: Aug. 29, 1972

Appl. No.: 284,465

Foreign Patent Priority Data

Nov. 25, 1971 Japan............................................. 46-94949

U.S. Cl. .......... 264/168; 161/177; 264/177 F
Int. Cl. 3......... D01D 5/22

Field of Search .... 264/177 F, 168; 161/177; 425/464, 382.2

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ABSTRACT

Crimped filaments of which cross sectional shape consists of a substantially circular basic part and two or three projections therefrom, said projections being located on one semicircumference of the circular basic part and satisfying the specific α and A/B values, parameters therefor. Filaments having such a novel structure have good crimp characteristics. The filaments are produced by the specific non-symmetrical quenching process.

2 Claims, 6 Drawing Figures
Fig. 4
(a)
(b)
METHOD FOR PRODUCING CRIMPED FIBERS

This invention relates to synthetic fibers of a new structure having reversed coil-like crimps, and to a method for producing these fibers. Examples of the synthetic fibers having crimpability include conjugate fibers obtained by melt-spinning polymers of different properties from the same nozzle, quenched non-symmetrical fibers obtained by quenching spun fibers immediately after extrusion to provide a difference in microstructure in the transverse direction of the fibers, and fibers mechanically crimped by, for example, a stuffing box process.

Conjugated fibers have high crimpability, and woven and knitted fabrics obtained from them have superior bulkiness and feel. But two or more polymers of different properties are needed, and complicated melt-extruder, piping and spinneret are required in order to produce them. Hence, the fibers obtained become high in cost.

In the conventional quenched non-symmetrical fibers, the difference in microstructure in the transverse direction of the fibers is provided by the difference in the rate of cooling the polymer immediately after extrusion, and the resulting fibers are far inferior in crimpability to the conjugate fibers. Furthermore, if in an attempt to render the structural difference larger, a greater amount of cooling air is used, the spinning conditions become extremely worsened, and breakage of the filaments occurs. Therefore, the operation becomes impossible. Furthermore, the mechanically crimped fibers do not have satisfactory stability and uniformity of crimps and, fine crimps cannot be obtained.

An object of this invention is to produce synthetic fibers having superior crimpability comparable to that of the conjugated fibers, by a simple production process and at low cost of production.

Another object of this invention is to provide synthetic fibers which are especially suitable for use in carpets or paddings for bedding.

Other objects of this invention will become apparent from the following description.

According to the present invention, there are provided fibers of an organic linear synthetic polymer, whose cross sectional shape consists of a substantially circular basic part at the center and two or three projections therefrom at least containing a standard projection and an adjacent projection. The standard projection has a cross sectional area not smaller than that of the other projections; and the central angle \( \alpha \) formed between the standard projection and the adjacent projection with respect to the center of the basic part is 45° \( \leq \alpha \leq 135° \). When the number of the projections is three, (three projections being located on one semicircumference of the basic part), the ratio of the cross sectional area A of the basic part to the cross sectional area B of the standard projection is 9 \( \leq A/B \leq 50 \). The degree of molecular orientation in the standard and adjacent projections being larger than that in the basic part and the degree of molecular orientation varies continuously in the cross sectional direction of the fibers. The fibers have the reversed coil-like crimps.

The synthetic fibers having reversed coil-like crimps are produced by melt-spinning of a fiber-forming organic synthetic polymer through a spinneret having a number of orifices, characterized in that each orifice comprises a substantially circular main hole and two or three subholes having smaller sizes than the main hole and provided in proximity to the surrounding of the main hole, said subholes at least containing a standard subhole and an adjacent subhole, the standard subhole having an area not smaller than that of the other subhole, the central angle \( \alpha' \) formed between the standard subhole and the adjacent subhole with respect to the center of the main hole being 45° \( \leq \alpha' \leq 135°C \), and when the number of the subholes is three, these three subholes being provided in proximity to one semicircumference of the main hole; a cooling air is blowing against the filaments extruded from a spinneret at substantially right angles to the individual filaments within a region 45 to 380 mm below the spinneret face, the direction of blowing the cooling air being in substantial correspondence with the direction connecting the center of the main hole with that of the standard subhole.

The present invention will be described in greater detail with reference to the accompanying drawings in which:

FIG. 1 shows that the state of flow of a cooling air at the time of producing the fibers is different in the method of the present invention and the conventional non-symmetrical quenching method;

FIG. 2 shows one example of the distribution of the degree of orientation of the cross-section of the fibers in comparison with the non-symmetrical quenched fibers;

FIG. 3 shows various shapes of orifices to be used in the production of synthetic fibers in accordance with this invention;

FIG. 4 is a photograph showing an enlarged scale the reversed coil-like crimps which are inherent to the synthetic fibers of this invention; and

FIG. 5 and 6 illustrate the relation between retardation and shrinkage, and the relation between shrinkage difference and the radius of curvature of the crimps, in order to explain the characteristic features of the fibers of this invention.

The method of this invention is a kind of non-symmetrical quenching; however, by the improvements of this invention, there can be formed synthetic fibers having a far superior crimpability to those of the conventional non-symmetrical quenching spinning method. Before going into the detailed description of the method of this invention, we will make a general survey on the mechanism by which fibers having crimpability are obtained by the non-symmetrical quenching spinning method. In a melt-spinning method in which a polymer melt is extruded, let us take up the spinning process in which one filament is formed from one orifice. The following theoretical equations of thermal balance can be provided under some assumptions:

\[
\nu \frac{\partial \theta}{\partial x} + \frac{\partial \theta}{\partial t} = \frac{2 \sqrt{\pi} h (\theta^* - \theta)}{\rho C_v \sqrt{S}}
\]

wherein \( x \) is the distance from the spinneret, \( t \) is the time required for the melt to reach position \( x \) after leaving the spinneret, \( \theta \) is the temperature of the melt, and \( \theta^* \) is the temperature of the atmosphere. Assuming that the variables do not change with time, the solution to this equation in the steady state is as follows:

\[
\nu \frac{\partial \theta}{\partial x} = \frac{2 \sqrt{\pi} h (\theta^* - \theta)}{\rho C_v \sqrt{S}}
\]
wherein \( S \) is the cross sectional area of the filament, \( \rho \) is the density of the filament, \( C_p \) is the specific heat of the filament, and \( h \) is the thermal conductivity of the filament.

If the speed of filament travel is \( V \) and the velocity of cooling air supplied at right angles to the filament is \( V_a \), the thermal conductivity \( h \) is given as follows by the experimental formula:

\[
\frac{h}{\rho V_a} = 0.473 \times 10^{-15} S^{-0.631} (V + (80)^{0.17})^{1.17}
\]

By substituting this \( h \) for the \( h \) in equation (1), we get equation (2) as follows:

\[
\frac{d\theta}{dx} = 1.68 \times 10^{-5} \frac{S^{-0.631} V_a^{0.17}}{(V + (80)^{0.17})^{1.17}} \left[ 1 + \left( \frac{V_a}{V} \right)^{0.17} \right] \frac{(\theta_s - \theta)}{\rho C_p}
\]

The reason why fibers having crimpability are obtained by the non-symmetrical quenching spinning method is that by the non-symmetrical cooling, the value \( (d\theta/dx) \) varies from place to place in the sectional direction of the fibers, and as a result, a difference is brought about in microstructure in the sectional direction of the fibers. In order to obtain the highest possible crimpability, differences in \( (d\theta/dx) \) according to place need to be rendered as large as possible in the sectional direction of the fibers.

Each of the orifices drilled in the spinneret used in the method of this invention consists of a substantially circular main hole at the center and two or three subholes provided in proximity thereto and having a smaller sectional area than the main hole (in the present specification and claims, a subhole having the largest sectional area as shown in FIG. 3 is called a standard subhole, and the subhole located just adjacent to the standard subhole is called an adjacent subhole), as shown in FIG. 3. As a result, the polymer melt extruded from each orifice forms a filament whose cross sectional shape consists of a circular base part (formed from the main hole) and two or three projections (formed from the subholes), as shown in FIG. 1. (a) or (b). In this filament, the projection formed correspondingly to the standard subhole (in the present specification and claims, this projection is called a standard projection) has a cross sectional area of one-ninth to 1/fiftieth of the area of the base part. The relative sizes and positions of the main hole and the standard subhole should be determined so that each filament formed meets these conditions.

According to the method of this invention, cold air is blown against the filaments obtained substantially at right angles thereto within an area ranging from the spinneret face to 45 - 380 mm below it, and the blowing direction of this cold air is brought into substantial agreement with the direction of connecting the centers of the standard subhole and the main hole in each orifice. By regulating the blowing direction of the cold air in this way, the relation between the filament and the blow line of the cold air is shown, for example, in FIG. 1. (a) and (b). Since the standard projection faces the blowing direction of cold air, \( V_a \) becomes large, and by its influence, the atmospheric temperature \( \theta_s \) naturally becomes lower. Furthermore, since the area of the standard projection is sufficiently smaller than the area of the base part, the heat capacity of the standard projection is very small as compared with that of the base part. It will be readily seen from equation (2) that the absolute values of \( (d\theta/dx) \) in all standard projections become larger than that of the base part owing to these factors. As regards the projection formed from the adjacent subhole (in the present specification and claims, this will be called an adjacent projection), the absolute value \( (d\theta/dx) \) becomes considerably larger than that of the base part for the same reason as set forth above with respect to the standard subhole. On the other hand, as shown in FIG. 1, (a) and (b), a zone not affected by cold air is formed by the action of the adjacent projection and a third projection which may be present. Since the influence of cold air is not direct in this zone, \( V_a \) is equal to zero, and the atmospheric temperature \( \theta_s \) becomes considerably higher than the temperature of the cold air because of heat emitted from the melt. As will be apparent from the above description, the absolute values of \( (d\theta/dx) \) of the standard projection and the adjacent projection are considerably larger than the absolute value of \( (d\theta/dx) \) of the base part in the fibers of this invention. As a result, the degree of the molecular orientation of the filament at the standard projection and the adjacent projection becomes considerably higher than that at the base part, and the degree of molecular orientation progressively decreases from these projections towards the base part. Change in the degree of molecular orientation in the sectional direction of the fibers is schematically shown in FIG. 2. (a). In FIG. 2, (a), the degree of molecular orientation in the cross sectional direction of the fibers is roughly indicated on a scale of three grades, high, medium and low which are shown respectively by the crisscrossed lines, spaced parallel lines, and blank portion. Actually, the degree of molecular orientation increases continuously in the direction of arrow in the drawing. Since the fibers of this invention have at least two projections having a degree of molecular orientation higher than that of the central base part, the sectional shape and the molecular orientation distribution of the fibers become very asymmetrical, and because of this, the fibers take the form of reversed coil-like crimps as shown in FIG. 4. In order to produce a fiber structure as asymmetrical as possible, it is effective to blow cold air against the standard projection which has the largest area, and also it is necessary that the central angle \( \alpha \) formed between the standard projection and the adjacent projection with respect to the center of the base part is between 45° and 135°, and preferably between 80° and 100°. Three projections may be present, and in this case, the three projections need to be present on one semicircumference of the base part in order to provide a highly asymmetrical structure. In other words, all of the three projections should be on one side of the base part. The presence of four or more projections is not effective to provide high asymmetry, but rather produces an adverse effect and also leads to increased cost of production.

The excellent crimpability imparted to the fibers of this invention is due to the asymmetry of the fiber structure in the sectional direction. However, if the sectional area of the projections is too small as compared with that of the base part, the effect of inducing asymmetry by the projection having a high degree of molecular orientation is reduced to an undesirable extent. It is therefore necessary that the cross sectional area \( B \) of the standard projection should be at least one-fiftieth of
the sectional area A of the base part. On the other hand, if the area of the projections is too large, the difference in \( \frac{dE}{dx} \) between the projections and the base part becomes smaller, and therefore the difference in the degree of molecular orientation between the projections and the base part also decreases. Hence, the necessary degree of asymmetry cannot be obtained. It is therefore necessary that the area B should not be larger than one-ninth of the area A. Preferably, the ratio A/B is between 9 and 17.

Orifices of various shapes can be used in the method of this invention as shown in FIG. 3 in which the arrow shows the direction of flow of cold air. From the viewpoint of the cost of drilling, orifices such as those shown in FIG. 3, (c) or (d) are preferred, in which the main hole is spaced from the subholes by a short distance. In an orifice of this type, the polymer melts extruded from the main hole and the subholes in spaced relationship coalesce immediately below the spacer to form a filament as shown in FIG. 1, (a) or (b), respectively. In order to ensure smooth coalescing, it is desirable that the distance between the main hole and each of the subholes should be less than the diameter of each subhole. Furthermore, in the orifice used in this invention, the ratio of the area of the main hole to the area of the standard subhole should be determined so that the ratio of the area A of the base part to the area B of the standard projection (A/B) is between 9 and 50. Such preferred ratio can be easily determined by experiment. Generally, the size of the main hole is 0.6 to 2.0 mm, preferably 0.7 to 1.5 mm in terms of the diameter of the corresponding circle, and the size of the subhole is 0.1 to 1.0 mm, preferably 0.2 to 0.7 mm, in terms of the diameter of the corresponding circle.

In the orifice shown by (a) or (b) of FIG. 3, in which the main hole is connected to the subholes by slits, the width of the slits is smaller than the diameter of each subhole, preferably one-third to one-fourth of the diameter of the subhole, and the length of the slits is not more than 0.5 mm, preferably 0.1 to 0.2 mm.

In order to provide a central angle \( \alpha \) formed between the standard projection and the adjacent projection of 45° to 135°, it is necessary that the central angle \( \alpha' \) formed between the standard subhole and the adjacent subhole with respect to the center of the main hole should be between 45° and 135°. Usually, \( \alpha \) and \( \alpha' \) are substantially the same. Where there are three subholes, they should be provided in proximity to one semicircle circumference of the main hole. The temperature of the cold air should preferably be between 10°C and 40°C, and the velocity of the cold air between 2 and 12 m/sec.

Preferred polymers that can be used as a fiberforming material are polyesters, polyamides and polypropylene. The polyesters are especially suitable. The term "polyesters," as used in the present specification and claims, is meant to include linear homopolymers derived from a dicarboxylic acid component such as aromatic dicarboxylic acids, e.g. terephthalic acid, isophthalic acid, naphthalene-2,6-dicarboxylic acid, 1,2-bis(p-carboxyphenyl)-ethane or 2,2-bis(p-carboxyphenoxymethyl)propane, aliphatic dicarboxylic acids, e.g. adipic acid or sebacic acid, or esters thereof, and a diol component such as ethylene glycol, diethylene glycol, neopentyl glycol, or cyclohexane-1,4-dimethanol; copolyesters thereof; and polyesters obtained by the homopolymerization of hydroxydicarboxylic acids. The polyesters may contain up to 30 mol% of a third component such as polyalkylene glycols, glycerine, pentaerythritol, methoxypolyalkylene glycols, bisphenol A, para(β-hydroxyethoxy)benzoic acid, 3-methoxy-4-(β-hydroxyethoxy) benzoic acid or sulfosuccinic acid. Polyethylene terephthalate is most preferred as the polyester.

The filaments extended by the method of this invention possess latent crimpability, and in this state, are wound up on a suitable winder. Then, the filaments are drawn, and heat-treated in accordance with the customary techniques. The latent crimps become actual helical crimps when the drawing tension is released. Alternately, the filaments are heat-treated in the relaxed state. The number of crimps thus obtained is usually 4 to 30, and preferably 5 to 20, per inch of the filament.

For comparison, a filament was formed by the conventional non-symmetrical quenching spinning method using an ordinary circular orifice, and the relation between the filament formed and the blowing line of cold air is shown in FIG. 1, (c). Changes in the degree of conventional molecular orientation in the sectional direction of the fibers are schematically shown in FIGS. 2, (b) by the same method as in FIG. 2, (a). It will be readily seen from these figures that the fibers of this invention are far more asymmetrical than those obtained by the conventional asymmetrical quenching spinning method.

Generally speaking, the crimping properties of fibers are evaluated by the number of crimps. The number of crimps depends upon the radius of curvature of the crimps, and when the number of crimps is larger with smaller radii of curvature the crimping properties are evaluated as good. The radius of curvature of the crimps is also greatly affected by the difference in the degree of molecular orientation within the cross section of the filament, and therefore by the difference in shrinkage. This relation is clear from the experimental results shown in FIGS. 5 and 6.

FIG. 5 shows the relation between the retardation and the shrinkage of polyethylene terephthalate filaments which were obtained by drawing polyethylene terephthalate filaments having an inherent viscosity of 0.62 (as measured by a Ubbelohde viscometer in a constant temperature vessel at 30°C, using a mixture of tetrachloroethane and phenol in a weight ratio of 1:1) obtained with various spinning drafts by a customary method, to 180% in an aqueous solution at 75°C, and then heat-treating the filaments in hot air at 140°C for 5 minutes. In filaments obtained by a customary method, there is hardly any difference in retardation within the cross sectional surface of the filaments such as shown in FIG. 2. The filaments obtained by a customary method have little difference in the degree of molecular orientation in the sectional direction of the fiber as shown in FIG. 2. The measurement of retardation (Γ) was made by the method described in Volume 4 of Kobunshi Jikken Gaku Koza (Lectures in Experimental Science of Polymer). "Physical Properties of Polymer, II" (Chapter 3). With the conventional asymmetrical quenched filaments, the difference between the retardation of a region having a high degree of molecular orientation and that of a region having a low degree of molecular orientation is at most 300, and if the difference is larger, the spinning condition becomes remarkably worsened.

FIG. 6 shows the relation between the shrinkage difference and the radius of curvature of crimps of a conjugate filament prepared by co-spinning two components whose shrinkage difference is known on the basis
of each component produced separately, drawing the conjugate filament to 180%, and then heat-treating the filament for 5 minutes in hot air at 140°C. Since in the conventional quenched asymmetrical filaments the difference in retardation is not more than 300, the shrinkage difference is also not more than 2%, which relation is shown by the hatched portion of FIG. 6. Therefore, none of these conventional filaments have a radius of curvature of less than 1 mm. In contrast, in the filaments of this invention, the difference in retardation between a region having a high degree of molecular orientation and a region having a lower degree of molecular orientation is as much as 500 to 1,400, and therefore, the filaments have a shrinkage difference of 2 to 6%. As is seen from FIG. 6, it is possible to obtain filaments having a crimp radius of curvature of less than 1 mm. The region occupied by the filaments of this invention is shown by the crosshatched lines in FIG. 5.

Uniformity of crimps can be further improved by modifying the process of this invention, and crimped filaments having superior feel and appearance can be obtained. This modified process comprises subjecting the filaments to asymmetrical cooling by cold air in accordance with the method described above, then drawing the filaments, subjecting the filaments to mechanical crimp to provide 5 to 15 crimps per inch, then spreading the filaments in the form of tow to reduce the apparent density of the tow to less than 0.15 g/cm², and further heat-treating the tow under no tension. Filaments produced by the asymmetrical cooling spinning method are imparted crimpability by this method itself, and therefore, usually not subjected to mechanical crimping. But in this modified method, it is intended to obtain a further improvement in crimpability by jointly employing the asymmetrical cooling spinning method and the mechanical crimping method, and then subjecting the filaments to the specified treatment. Extruded filaments are asymmetrically cooled by cold air blown against the filaments within a region 45 to 380 mm below the spinneret, and wound up on a winder. The filaments are then drawn by a customary method, and then mechanically crimped, for example by subjecting them to a stuffing crimp, or gear crimp to provide 5 to 15 crimps per inch of the filaments. After crimping, the apparent density of the filaments is reduced to below 0.15 g/cm², preferably below 0.08 g/cm², and the filaments are heat-treated. The filaments are then cut to suitable sizes to obtain staple fibers having superior uniformity, bulkiness, feel, appearance and passability through a carding machine.

The "apparent density of the tow" is calculated from the weight of the tow placed in a can with a height of 90 cm, a length of 60 cm and a width of 30 cm by spontaneous falling and the inner capacity of the can (the moisture content of the tow is maintained at 2 - 4%). Tows prepared by a customary method have an apparent density of about 0.15 to 0.25 g/cm². Reduction of the apparent density of the tow can be effected by spreading the tow using an air jet. The heat-treatment is usually carried out at a temperature of 100°C to 200°C. under no force or restraint on the tow.

The invention will be described further by the following Examples.

EXAMPLE 1

A melt of polyethylene terephthalate containing 0.05 mol% of pentaerythritol copolymerized therewith and having an inherent viscosity of 0.62 was spun using a spinneret having 204 orifices of the shape as shown in FIG. 3, (b) at a rate of 227 g/min. The central angle was 82°. The temperature of the spinneret was 283°C, and cold air was directed at right angles to the extruded filaments in the direction of the arrow in FIG. 3 within a region of 5 to 10 cm below the spinneret. The temperature of the cold air was 30°C, and the velocity of the air was 5 m/sec. The spinning drum was 650, and the take-up speed was 680 m/min. The filaments obtained were drawn to 2.6 times the original lengths in a water bath at 70°C, and then in a water bath at 90°C, to a total draw ratio of 3.0 times the original lengths. The drawn filaments were heat-treated in the relaxed state in a drier at 110°C. for 5 minutes to form a yarn with an average monofilament denier of 6.

The filaments obtained had an A/B ratio of 10, and contained 11 reversed coil-like crimps per inch of the filament length. Examination of optical microscope showed that the crimps had a radius of curvature of 0.7 mm. The filaments were cut to a length of 84 mm, and subjected to a carding machine. Using the resulting fibers as padding, a covering for a home heater of portable size was prepared. It had very good bulkiness and compression elasticity, as shown in Table 2.

EXAMPLE 2

A melt of polyethylene terephthalate having an inherent viscosity of 0.60 was spun using a spinneret having 92 orifices of the shape shown in FIG. 3, (a) The central angle α was 90°. The temperature of the spinneret and the conditions for the cold air were the same as in Example 1, but the rate of wind-up was 700 m/min. and the draft was varied as shown in Table 1. The filaments were drawn in a water bath at 90°C at a ratio 90% of the maximum draw ratio (draw ratio at which the monofilaments begin to break). The conditions for the heat-treatment under relaxed conditions were the same as in Example 1.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Draft (times)</th>
<th>A/B</th>
<th>Tmax - Tmin</th>
<th>R (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>500</td>
<td>9</td>
<td>980</td>
<td>0.6</td>
</tr>
<tr>
<td>2</td>
<td>700</td>
<td>12</td>
<td>1940</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>800</td>
<td>14</td>
<td>1230</td>
<td>0.3</td>
</tr>
</tbody>
</table>

The A/B difference in retardation (the cross section is divided into three regions of high, medium and low retardations shown in FIG. 2, (a), and the average value of retardation in the region having a high retardation is ɣmax, and the average value of retardation in the region having a low retardation is ɣmin), and the radius of curvature of the crimps by microscopic observation of the obtained sample filaments are shown also in Table 1 above.

Each of the samples was blended with 40% of Vynilon (polyvinyl alcohol fibers), and using this blend, a russet tufted carpet having a pile length of 6 mm was produced, which showed superior bulkiness and pile recovery power compared to the conventional carpet produced from filaments of the ester type.

COMPARATIVE EXAMPLE 1

The procedure of Example 1 was repeated using a spinneret having 204 orifices of an ordinary circular shape with a diameter of 0.8 mm. The properties of the resulting filaments are shown in Table 2 in comparison with those of the filaments obtained in Example 1. A
covering for a home heater of the portable size was produced using the fibers prepared in the same way as in Example 1. The results are also shown.

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{( \text{Tmax} - \text{Tmin} )} )</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Product</td>
</tr>
<tr>
<td>of this invention</td>
</tr>
</tbody>
</table>

In the table bulkiness is the height of three superposed paddings containing the obtained fibers each of which was folded in quarto (300 g \( \times \) 3 = 900 g). This height is referred to as \( a \) mm. The elastic recovery is measured by applying a load of 1 kilogram from the upper part of the three superposed paddings, and allowing them to stand for 5 days in a room held at 20°C and a humidity of 65%, after which the load is removed. The height at this time is referred to as \( b \) mm. The elastic recovery is calculated by the following formula:

\[
\left( \frac{a - b}{a} \right) \times 100 \% 
\]

It is clear from Table 2 that the filaments of this invention have a smaller radius of curvature of the crimps than the conventional product, and that the paddings produced had good bulkiness and especially good elastic recovery. Even when the covering containing these paddings was washed as a whole, break of the paddings did not occur at all, and it exhibited a feather-like touch.

**EXAMPLE 3**

Polypropylene having a molecular weight of 75,000 was spun at 280°C using a spinneret having 92 orifices of the shape shown in FIG. 3, (a) and in the same way as in Example 1. Cold air was applied to an area ranging from 5 cm immediately below the spinneret to 15 cm below it at a rate of 3.5 m/sec. so that the standard subhole was first cooled, followed by wind up. The filaments were drawn in a water bath at 90°C., and cramped and spread and heat-treated to form paddings for beddings having a denier of 12. The filaments had 15 reversed coily crimps per inch of the filament length, and exhibited very good compression properties.

**EXAMPLE 4**

Nylon-6,6 having a melt viscosity of 275°C. of about 2,000 poises was spun using a spinneret with 204 orifices of the shape shown in FIG. 3 (a). Cold air was applied to the filaments in a region ranging from 10 cm below the nozzle to 15 cm below it at a speed of 4 m/sec. The filaments were wound up so that the subholes were first quenched. The filaments were drawn in a water bath at 50°C, and then cramped to form 15 crimps per inch of the filament length, followed by spreading and heat-treatment to form staple fibers having a monofilament denier of 6. The fibers had 18 reversed coily crimps per inch, and exhibited good bulkiness.

**EXAMPLE 5**

A melt of polyethylene terephthalate having an inherent viscosity of 0.58 was spun using a spinneret having 204 orifices with the shape shown in FIG. 3, (a). The temperature of the spinneret was 285°C. The amount of extrusion per 204 holes was 208 g/min., and the rate of take up was 600 m/min. Cold air at 20°C. was applied at a velocity of 7 m/sec. at right angles to the extruded filaments in a region of 15 cm between a point 5 cm below the spinneret and a point 20 cm below it. The extruded filaments were collected to form a 500,000 denier tow. The tow was drawn to a total of 2.2 times the original length in two stages in a water bath at 80°C. and then in a water bath at 98°C. The drawn tow was mechanically cramped by a stuffing crimper with a roller width of 30 mm so as to provide 6 to 8 crimps per inch. An air jet was blown against the cramped tow to spread the tow so that the apparent density of the tow became 0.07 g/cm³. In this spread state, the tow was heat-treated for 10 minutes with hot air at 152°C. under no tension. The tow was then cut to a length of 64 mm. The developed crimps were very uniform. The cut tows were subjected to a card to form paddings for beddings. They had good passability through a card, and the paddings obtained had excellent bulkiness and soft feel and compression elasticity.

**EXAMPLE 6**

Filaments were produced in the same way as in Example 5 except that the number of crimps was 10 to 12 per inch and the apparent density of the tow was 0.04 g/cm³. The developed crimps were uniform, and the filaments had superior passability through a card. The product had superior bulkiness and compression elasticity. The touch of the product was somewhat harder than that of the product obtained in Example 5.

What we claim is:

1. A method of producing fibers and filaments by spinning a melt of a fiber-forming organic linear synthetic polymer through a spinneret having a number of orifices, characterized in that each orifice comprises a substantially circular main hole and two or three subholes having smaller sizes than the main hole and provided in proximity to the surrounding of the main hole, said subholes at least containing a standard subhole and an adjacent subhole, the standard subhole having an area not smaller than that of the other subhole, the central angle \( \alpha' \) formed between the standard subhole and the adjacent subhole with respect to the center of the main hole being \( 45^\circ \leq \alpha' \leq 135^\circ \), and when the number of the subholes is three, these three subholes being provided in proximity to one semicircumference of the main hole; a cooling air is blown against the filaments extruded from a spinneret at substantially right angles to the individual filaments within a region 45 to 380 mm below the spinneret face, the direction of blowing the cold air being in substantial correspondence with the direction connecting the center of the main hole with that of the standard subhole.

2. The method of claim 1, wherein the filaments are drawn after application of the cold air, and mechanically cramped to provide 5 to 15 crimps per inch, and thereafter the filaments are spread in the form of a tow to reduce the apparent density of the tow to less than 0.15 g/cm³, and then the tow is heat-treated under no tension.