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[54] **PROCESS FOR THE MANUFACTURE OF THREE-DIMENSIONALLY CRIMPED FIBERS AND FILAMENTS**

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[56] **References Cited**

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[57] **ABSTRACT**

A process is described for making three-dimensionally crimped fibers and filaments from synthetic high-polymers. Fibers and filaments with a double refraction gradient over their cross-sectional area, which have been obtained by known methods, are drawn and subsequently dried at temperatures within the range of from 50° to 230°C without any shrinkage. After drying, the crimp is developed at temperatures within the range of from 60° to 230°C with the filaments being free from any tension.

10 Claims, No Drawings

PROCESS FOR THE MANUFACTURE OF THREE-DIMENSIONALLY CRIMPED FIBERS AND FILAMENTS

The present invention relates to a process for the manufacture of three-dimensionally crimped fibers and filaments.

Various processes have been proposed for making polyester filaments having a helical crimp which is very similar to the natural crimp of wool. The common principle of these processes consists in subjecting the filaments which have been freshly spun in the melt and are still hot to a rapid unilateral cooling carried out immediately below the spinning nozzle. The cooling may be brought about by unilaterally blowing the hot filaments with cold air as described in U.S. Pat. No. 3,050,821, or by means of a thin liquid film on a porous hollow body as in British Pat. No. 809,273, or in a dry way on an appropriate cooling body as disclosed in Belgian Pat. No. 708,919. In all these processes, the unilateral cooling of the spun filaments in the plastic state results in an orientation of the macromolecules which decreases over the cross-sectional area of the filament from the cooled to the warm side of the filament. This orientation gradient is preserved during the following drawing process and produces a latent crimp because the two sides of the filament have different capabilities of contracting. The crimp can then be developed by heating the drawn dried filaments while allowing them to shrink.

Various processes have been described for developing a latent crimp. According to one of these proposals, the drawn filaments are heated; before heating, the filaments are advantageously cut to staple length. The fiber is heated without tension for 15 minutes at 140°C in hot air (cf. U.S. Pat. No. 3,050,821).

In another known process, the crimp is developed in such tows after drawing either by passing the two through a heating zone disposed between two conveying devices or by suspending loose ropes of the two in a heated oven for free shrinking (cf. British Pat. No. 809,273).

These known processes suffer from the disadvantage that, prior to developing the crimp, the fibers and filaments must be dried completely at low temperatures, for example filaments of polyethylene terephthalate at a temperature below 60°C, in order to preserve the orientation gradient over the cross-sectional area during drying. When drying is carried out at elevated temperatures, the differences in orientation are levelled in the individual filaments so that the original latent crimp cannot be developed because it has been destroyed by drying.

The present invention provides a process for the manufacture of three-dimensionally crimped fibers and filaments of synthetic high-polymers, preferably polyesters, and more particularly polyethylene terephthalate, starting from filaments or tows to which a latent crimp has been conferred by producing an orientation gradient over the cross-sectional area, which process comprises drawing the filaments or tows, drying them at temperatures within the range of from 50°C to 230°C without permitting shrinkage, and finally developing the crimp at temperatures within the range of from 60°C to 230°C in the absence of any tension.

In a preferred mode of executing the process of the invention, the drawn filaments or tows are dried at a temperature within the range of from 50°C to 230°C without permitting shrinkage, then cooled to a temperature below 50°C also without permitting shrinkage, and finally subjected to a heat treatment at a temperature within the range of from 60°C to 230°C, preferably 90°C to 130°C, without any tension in order to develop the crimp. In another advantageous form of the process of the invention, the drying is carried out in a temperature range the lower limit of which is 20°C below the second order transition temperature and the upper limit of which is at least 35°C below the melting point of the filaments, and preferably at a temperature within the range of from 90°C to 160°C.

The process in accordance with the invention is preferably carried out such that the filaments or the two are or is after-drawn during drying and cooling by 1 to 50 percent, preferably 1 to 10 percent, calculated on the length of the filaments or the tow before said after-drawing. All process steps are advantageously carried out in a continuous manner on a moving tow.

The process of the invention can be carried out in industry in a simple manner with the usual devices. The undrawn filaments, either a small number thereof or a thick tow (for example 500,000 dtex), are passed through a brightening bath containing the substances commonly used for favorably influencing the sliding and adhesion properties of the fibers and preventing electrostatic charge. The filaments or the tow are then squeezed-off and drawn between two septet rollers. The drawn tow is conducted over a further two drawing devices which act in he same way as the two first conveying devices used for the main drawing process. The third roller unit has at least the same conveying speed as the second roller unit, while the fourth roller unit has at least the same conveying speed as the third roller unit so that the tow cannot shrink between the second and the third drawing device during drying. It is advantageous to after-draw the tow during drying as well as during cooling by 1 to 50 percent, preferably 1 to 10 percent.

The distances between the individual drawing devices depend on the possibilities of drying and cooling and are such that the tow, when leaving the fourth drawing device, has been dried completely and cooled to below 50°C. Drying is performed on the second drawing device if a sufficient amount of heat can be supplied to the rollers thereof by means of steam or heating liquid. Alternatively the tow may be dried between the second and the third drawing device on a heated metal surface, in hot air, by infrared heating or in a high-frequency electromagnetic alternating field. Drying is advantageously carried out in a temperature range the lower limit of which is 20°C below the second order transition temperature and the upper limit of which is at least 35°C below the melting point of the filaments, preferably at a temperature within the range of from 90°C to 160°C. In an analogous manner, cooling is carried out on the third or the fourth drawing device if a sufficient amount of heat can be eliminated from the rollers thereof by a cooling liquid flowing through the interior of the rollers, or cooling is performed between the third and the fourth drawing device using a metal surface or a streaming medium capable of eliminating a sufficient amount of heat from the tow.

Under certain conditions, the process may also be carried out using only three drawing devices. In this case, the brightening agent is applied to the undrawn tow before drawing and thoroughly squeezed-off. The tow is then drawn between the first and the second roller unit. The second roller unit is kept at a sufficiently high temperature by a heating liquid or superheated steam so that the tow is completely dry when leaving this roller unit. The third drawing device may be cooled by a circulating liquid to such an extent that the tow has been cooled to below 50°C when it leaves the rollers.

It is advantageous to sufficiently precool the tow in this case between the second and the third drawing device on a cooled metal surface or simply in air.

If the crimp is only developed after cooling, it is an essential feature of the process of the invention to cool the tow which has been dried completely to a temperature below 50°C before reducing the tension, that is before allowing the tow to shrink.

After having been released from tension, the completely dry and sufficiently cooled tow has a slight crimp in large bends and the individual filaments do not stick together. To develop the crimp the tow is now subjected to a heat treatment at a temperature within the range of from 60°C to 230°C, preferably 90°C to 130°C, in a gaseous or liquid heating medium. The tow should be as free from stress as possible since the quality of the crimp which is being developed is considerably deteriorated even by the slightest tension in the direction of the axis of the filament, for example by the weight of 1 meter of filament. By "quality of the crimp" there is here meant the number of bends per centimeter of length of filament, the crimp retentivity and the recovery of the temporarily stuffed fibers. It has been found, for example, that when the crimp is developed between two neighboring conveying units the development of an optimum crimp is prevented by the tensile stress produced by the dead weight of the tow, even when the second conveying unit revolves so slowly that the tow sags a little. This tensile stress makes itself felt to the same extent in each place of the tow between the two conveying units. Contrary thereto, a considerably smaller stress is obtained in a simple manner if the tow is freely suspended and subjected only to the action of gravity. At the lower end of the tow the stress is equal to zero. In a continuously moving tow, the stress is very near this limiting value when the tow is run off, for example, in a perpendicular direction from a conveying unit onto a horizontally arranged conveyor belt disposed below, which conveys the tow. Immediately before striking the conveyor belt, the tow is under a minimum tensile stress. When it is blown at this point with steam or hot air, a fiber is obtained the crimp of which is superior as regards its quality to that of all other fibers obtained by a continuous process.

The crimped tow is fed by the horizontal conveyor belt to devices used for the continuous processing of the tow. The crimp is generally subjected to a thermosetting with the help of steam or hot air. The thermosetting as well as the cutting and packaging of the finished fibers may be carried out continuously in known manner.

The above fully continuous process enables the production of a fiber which has a crimp that is similar to that of native fibers and a dimensional stability that excels that of the known synthetic fibers.

The process in accordance with the invention is particularly suitable for the production of crimped filaments, fibers or tows of linear polyesters of high molecular weight. It is advantageously applied to linear polyesters of high molecular weight of which the acid component consists of at least 90 mol percent terephthalic acid units and the diol component consists of at least 90 mol percent ethylene glycol units.

The process is also applicable to fibers, filaments and tows of copolyesters or polyester amides.

After the valuable properties of helically crimped fibers and filaments have become known, an economic process for their manufacture is of interest to industry. In the fibers crimped in known manner in stuffing chambers, the crimp is limited to the places of bending. In said places of bending, the fiber has been strongly changed morphologically, which unfavorably affects the crimp retentivity. Contrary thereto, the helical crimp obtained in accordance with the invention is uniformly distributed over the entire length of the fiber as is the case with native fibers, so that the dimensional stability of fleeces or textile shaped structures made of such fibers is considerably improved.

Owing to these valuable properties, the fibers obtained by the process of the invention find new fields of application. They are suitable for use in all cases in which fibers having a good bulkiness combined with a good recovery from load are required.

The following Examples serve to illustrate the invention.

EXAMPLE I

A tow of 10 000 monofilaments which, during melt spinning, had been cooled on one side on a metal surface directly below the spinning nozzle and therefore had an orientation gradient, was passed at a rate of 23 m/min. through a brightening bath comprising an aqueous solution of an allyl phenyl polyglycol ether, aliphatic polyglycol ethers and fatty acid esters of dihydric alcohols, squeezed off and drawn in known manner in steam in the ratio of 1 : 2 between two 7-roller drawing devices. The spun filaments had been obtained by the process described in Belgian Pat. No. 708 919. The drawn tow was passed over a further two drawing devices, the third drawing device revolving 1.04 times faster than the second drawing device, and the fourth drawing device revolving 1.04 times faster than the third drawing device. Between the second and the third septet a metal body 4 meters long and 50 centimeters wide, of which the surface was heated at 140°C was disposed. Through the rollers of the third and fourth septet cooling water was passed in order to cool the tow on the roller surface to about 30°C. From the last roller of the fourth septet, the tow was allowed to fall freely 1 meter vertically downward onto a conveyor belt. Directly above the latter, superheated steam at a temperature of about 110°C was blown from both sides through the tow to develop the crimp, whereby the speed of the tow was strongly reduced. With a speed of rotation of 50 m/min. of the rollers of the fourth septet, the speed of the conveyor belt was adjusted to 10 m/min. The tow was conveyed by the conveyor belt to a heated channel in which it was heated to a temperature of 150°C within 60 seconds by hot air. After having left the setting channel the tow was allowed to cool and then cut in known manner.

The fiber so obtained had the following properties:

Tensile strength 3.1 p/dtex
Elongation at break 25 percent
K_1 20.3 percent
K_2 15.3 percent
Crimp retentivity 75.5 percent
Crimp 4 to 5 bends/cm

$K_1 = (l_1 - l_0)/l_1 \cdot 100$

l_0 = distance between grips (length of crimped fiber under a preliminary tension of 1.8 mp/dtex)

l_1 = length of the fiber after it has been de-crimped without any further drawing

$K_2 = (l_2 - l_0)/l_2 \cdot 100$

l_2 = length of the fiber after it has been de-crimped without any further drawing and then loaded and released; K_2 is measured after loading the fiber with 0.5 p/dtex for 1 minute and allowing it to recover for 1 minute.

EXAMPLE 2

In the manner described in Example 1, a tow of 50,000 monofilaments obtained by the process of the above Belgian Patent and having an orientation gradient was passed at a rate of 23 m/min. through a brightening bath, squeezed-off and then drawn in steam between two septets. The rollers of the second septet were heated with superheated steam to a surface temperature of 100°C so that the tow was completely dried after drawing. The distance between the second and the third septet was 5 meters. Here the tow cooled substantially in air at room temperature. The rollers of the third septet rotated at a speed of 48 m/min., that is 1.04 times faster than the second septet. They were cooled with water so that the tow had been completely cooled when it left the third septet. The tow was subjected without tension to a heat treatment to develop and set the crimp in the manner described in Example 1. The properties of the fiber corresponded to those indicated in Example 1.

What is claimed is:

1. A process for the manufacture of three-dimensionally crimped filaments or tows of synthetic high-polymers, starting from filaments or tows to which a latent crimp has been conferred by producing an orientation gradient over the cross-sectional area, which process comprises drawing the filaments or tows, drying them at a temperature within the range of from 50°C to 230°C without permitting shrinkage, and finally developing the crimp at a temperature within the range of from 60°C to 230°C in the absence of any tension.

2. The process of claim **1** wherein the drawn filaments or the tow are or is dried at a temperature within the range of from 50°C to 230°C without permitting shrinkage, cooled to a temperature below 50°C without permitting shrinkage, and subjected without any tension to a heat treatment within the range of from 60°C to 230°C to develop the crimp.

3. The process of claim **1** wherein the crimp is developed at a temperature within the range of from 90°C to 130°C.

4. The process of claim **1** wherein drying is carried out in a temperature range the lower limit of which is 20°C below the second order transition temperature and the upper limit of which is at least 35°C below the melting point of the filaments.

5. The process of claim **1** wherein drying is carried out at a temperature within the range of from 90°C to 160°C.

6. The process of claim **1** wherein the filaments or the tow is or are after-drawn during drying and cooling by 1 to 50 percent calculated on the length of the filaments or the tow before said after-drawing.

7. The process of claim **1** wherein the filaments or the tow is or are after-drawn during drying and cooling by 1 to 10 percent calculated on the length of the filaments or the tow before said after-drawing.

8. The process of claim **1** wherein all process steps are carried out continuously on a moving tow.

9. The process of claim **1** wherein the synthetic polymer is a polyester.

10. The process of claim **1** wherein the synthetic polymer is polyethylene terephthalate.

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