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W. J. PRIVOTT, JR., ET AL

3,387,327

FILAMENT SPINNING APPARATUS

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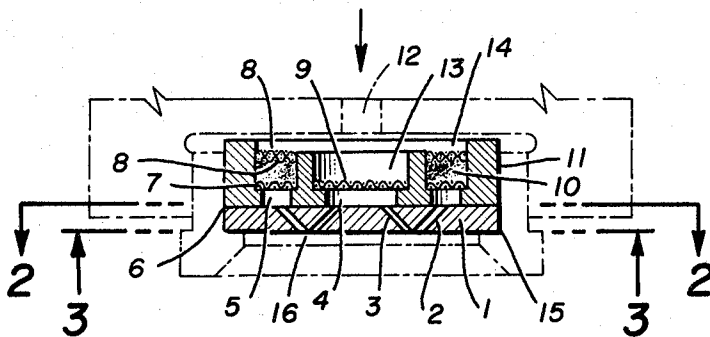


FIG. 1.

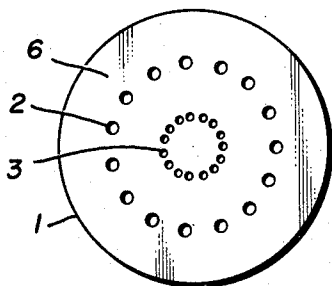


FIG. 2.

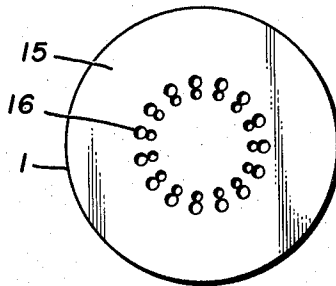


FIG. 3.

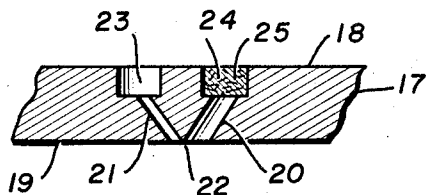


FIG. 4.

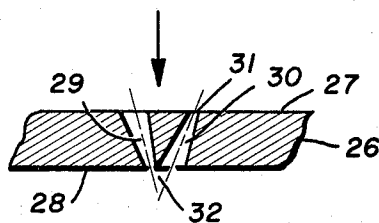


FIG. 5.

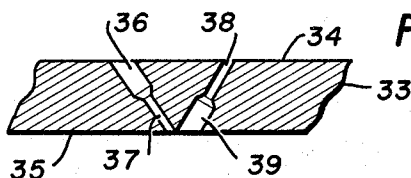
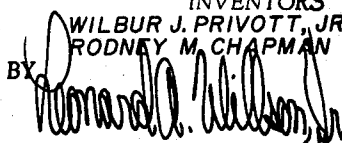


FIG. 6.

INVENTORS
WILBUR J. PRIVOTT, JR.
RODNEY M. CHAPMAN
BY  ATTORNEY

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FILAMENT SPINNING APPARATUS

Wilbur J. Privott, Jr., Raleigh, and Rodney M. Chapman,
Kinston, N.C., assignors to Monsanto Company, St.
Louis, Mo., a corporation of Delaware

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ABSTRACT OF THE DISCLOSURE

In this invention, a spinnerette produces a self-crimping filament from a source of a thermoplastic filament-forming material by admitting to an extrusion orifice at least two streams of different cross-sectional areas but substantially equal mass flow rates to form a mono-conjugated filament having, upon the stretching thereof, substantially different degrees of orientation across its cross-section.

This invention relates to an apparatus for producing synthetic textile fibers, and more particularly, to an improved spinnerette construction for the production of self-crimping synthetic filaments and fibers.

Various embodiments of apparatus for producing self-crimping composite synthetic filaments from two or more discrete and usually spinable mediums capable of forming filaments upon evaporation, coagulation or cooling are described in the prior art. However, such apparatus are handicapped by certain disadvantages, particularly as regards intricacies of construction and limitations on uniformity of product, which have limited their commercial utilization.

Typical of the prior art spinning apparatus employed to produce self-crimping bicomponent filaments are those wherein at least two discrete systems of fluid passageways interconnect two discrete sources of polymeric fiber-forming material with each spinning orifice, the distinct sources of material being maintained separate throughout the filament forming process until a point of merger is reached at or in close proximity to the extrusion orifice, wherein the spinning materials are united, normally in a side-by-side or sheath/core arrangement, into a unitary filament having a uniform cross-sectional distribution of the components throughout the length of each filament. By such a technique of pairing at least two disparate fiber-forming materials to form a single filament, such filament may be caused to possess a crimping potential upon suitable after-treatment due to a differential in physical properties between the components, especially as regards shrinkage and/or elastic recovery. A primary detriment suffered by such a technique resides in the necessity of providing separate melt sources and pump mechanisms with the attendant problem of maintaining the desired into-control between the separate systems. Also, such an approach relies on the inherent disparities and physical properties of the two fiber-forming mediums employed and, in many instances, it has been found most difficult, if not impossible, to accommodate the peculiarities of each melt in a conjugate spinning system, particularly as regards optimum melt and extrusion temperatures and gell rates, in the case of melt spinning.

A somewhat different approach to obtain a filament of self-crimping potential utilizes essentially only a single source of fiber-forming material which is conveyed as separate streams of differing thermal history (particularly as regards time and temperature) to thereby establish a disparity in those physical properties found to be productive of self-crimping capability. Another proposal for obtaining a filament of self-crimping potential does not rely on the merger of two or more streams of material having, or which are caused to have, disparate physical properties,

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but is essentially no more than conventional mono-component spinning accompanied by asymmetrical quenching to establish an asymmetric differential in birefringence over the filament cross section. Each of these approaches has been recognized to have shortcomings as regards uniformity of treatment and consequent uniformity of crimp formation, as well as being limited in their ability to produce filaments having a sufficiently high crimp capability for many applications.

In light of the foregoing problems and recognized shortcomings it becomes an object of the present invention to provide a spinning apparatus capable of producing filaments having self-crimping properties, each of which filaments is formed from the merger of two or more streams which may, though not necessarily, be of identical composition, thermal history and quench treatment. A further object of this invention is to provide a spinning apparatus capable of producing a plurality of such self-crimping filaments having a uniform cross section throughout their lengths and, in the preferred embodiment, having an equality of distribution of components formed from each of the several streams merged to form a given filament. Still another object of the invention is the provision of an improved spinnerette construction by which self-crimping synthetic filaments may be produced from a common source of polymeric fiber-forming material. Another object is the provision of a spinnerette construction for the production of self-crimping synthetic fibers, which construction involves only minor modifications of an otherwise conventional mono-component spinning system.

In accordance with the present invention, the foregoing and other objects are attained by providing, in a synthetic filament spinning system, an improved spinnerette construction characterized by at least one pair of converging passageways or orifice capillaries wherein the exit regions of such capillaries are of differing cross-sectional areas, whereby the fiber-forming medium passing through each of the capillaries is caused to issue into a common filamentary stream at different linear velocities. The differential in linear velocities of the constituent streams forming a given filament established by such a 'spinnerette construction results in a filament possessing an asymmetric differential in orientation when the filament, so extruded, is withdrawn from the orifice at a linear velocity exceeding that of any constituent stream. Upon drawing and/or optional heat relaxation, such an asymmetric differential in orientation over the filament cross section becomes manifest by a contortion of the hitherto straight filament into a helically crimped configuration of readily controlled frequency and amplitude. Such a "self-crimping" capability has been viewed as arising from a differential in elastic recovery after drawing and/or a differential in shrinkage upon, for example, heat relaxation, resulting in the generation of an imbalanced system of forces acting over the filament cross section to contort same into its crimped configuration. Whether by the mechanism of elastic recovery or shrinkage, the differential in response to the release of drawing tension or exposure to heat relaxation has been ascribed to the asymmetric differential in orientation over the filamentary cross section. In any event, it is among the objectives of the present invention to provide a novel and simplified means of effecting such a differential orientation.

The differential in jet-stretch to which a filament may be subjected by extrusion through the subject apparatus has a prime advantage in the ability to produce a self-crimping filamentary structure from a common melt source, which source may, in the preferred mode, be conveyed to the spinnerette itself as a single stream, at which point it is momentarily sub-divided through two or more discrete groups of capillaries of differing cross-sectional

exit areas, each of which groups of capillaries may comprise a plurality of individual capillaries supplying a plurality of orifices, hence merging two or more capillary streams from two or more of such groups of capillaries into a single stream having a differential in linear velocity over its cross section. It is to be recognized, however, that the concept of extruding constituent streams at a differential in linear velocity to form a unitary filament may advantageously be practiced in conjunction with conventional bicomponent spinning techniques and apparatus; for example, two chemically and/or physically disparate fiber-forming mediums, by virtue of the inter-relationship of certain of their chemical and/or physical properties, may be combined into a unitary filament having a self-crimping potential, which potential may be enhanced or modified by merging such disparate melts at differential linear velocities.

Also, though the following discussion shall be largely in terms of a side-by-side merger of constituent streams to form a unitary filament, the concepts herein disclosed may be as well practiced in the form of a sheath/core merger, wherein a core stream is injected into a sheath stream having a different velocity, with extrusion into a unitary filament occurring proximate to the point of such sheath/core merger. Similarly, a great variety of orifice cross-sectional configurations may as well be employed in utilization of the present spinning apparatus to produce self-crimping filaments having a wide variation in cross-sectional configuration.

The juncture of the orifice capillaries supplying a given orifice preferably meet substantially coincident with their points of exit at the downstream surface of the spinnerette plate, but it will be clear to those skilled in the art that such juncture may occur either somewhat prior to issuance through the orifice or somewhat downstream of the point of exit from the spinnerette face, the essential limitation being that two or more appropriate capillary streams may ultimately be caused to unite into a single unitary filament prior to substantial solidification, else separation of the constituent streams may be difficult or impossible to avoid. Also, the angle of convergence of the two or more capillaries forming a given filamentary stream has not been found critical to the extent that merger is not so abrupt as to generate turbulent flow and the consequent possibility of unduly blending the constituent streams. It is, however, contemplated that controlled amount of blending of the constituent streams may be desired in certain circumstances; viz, where it is found that component separation is a problem, such a blending of the interface between two or more constituent streams has been found to provide improved resistance to separation tendencies during further processing.

For a better understanding of the constructional details of the spinnerette apparatus constituting the present invention, reference is now had to the accompanying drawings as illustrating typical embodiments thereof and in which:

FIG. 1 is an axial cross section of one arrangement of the spinnerette assembly showing the alignment of the spinnerette capillaries, orifices and spinnerette pack assembly, which arrangement is particularly adapted to handling two disparate fiber-forming mediums, but is not limited thereto;

FIG. 2 is a plan view of the spinnerette interface taken along line 2—2 of FIG. 1 and showing pairs of large and small orifice capillaries arranged in a concentric circle pattern;

FIG. 3 is a plan view of the outer or orifice face of the spinnerette taken along line 3—3 of FIG. 1 showing the preferred concentric arrangement of spinnerette orifices;

FIG. 4 is an enlarged fragmentary cross-sectional view of another embodiment of the spinnerette capillaries and orifices shaped to embody the concepts of this invention;

FIG. 5 is an enlarged fragmentary view of still another

form of spinnerette capillaries and orifices according to this invention; and

FIG. 6 is an enlarged fragmentary cross-sectional view of a third embodiment of spinnerette capillaries and orifices configured according to the teachings herein.

Referring now to FIG. 1, there is shown in the assembled cross-sectional view a spinnerette assembly comprising a spinnerette pack 11 and a spinnerette plate 1 mounted in face-to-face relationship whereby appropriate passages within the pack and plate are placed in register to define continuous passageways throughout the assembly. Considering first the details of the spinnerette plate 1, as further illustrated in FIGS. 2 and 3, the plate may take the form of a circular disc having substantially parallel surfaces, viz, the upper or interface surface 5 and the lower or orifice surface 15. A plurality of pairs of capillaries 2 and 3 are provided in the spinnerette plate wherein capillary 2 is provided with a larger cross-sectional area in the vicinity of orifice 16 relative to that of capillary 3. In the embodiments illustrated, capillaries 2 and 3 are located in concentric circles, but virtually any other desired arrangement may be as well accommodated as, for example, chord-wise extending rows of orifices. The capillaries communicating with a given orifice are preferably formed in the spinnerette plate at an angle such that the capillary path lengths are substantially equal, both capillaries emanating from the orifice face of the plate 15 tangentially as a common conjugate orifice 16, as depicted in FIGS. 1 and 3.

An essential feature of this invention resides in the relationship between the cross-sectional areas of capillaries 2 and 3 in the vicinity of the orifice, which relationship is such as to impart a differential linear velocity in the constituent streams issuing from such orifice which, upon taking the resulting filament up at a linear speed exceeding that of any constituent stream, results in imparting an asymmetric differential orientation due to the differential jet-stretch thus imparted to the filament. As previously mentioned, the result is a filament having a differential response to either or both the release of a drawing tension, resulting in a spontaneous crimp formation, and a differential shrinkage in response to such as heat relaxation.

In accordance with our invention, it therefore follows that, to achieve self-crimping unitary filaments which, for purposes of illustration, contain no inherent disparity of properties such as may normally result in self-crimping capability, the ratio of the cross-sectional area of capillary 2 in the orifice region to that of capillary 3 must be greater than 1. That is

$$A_2/A_3 > 1$$

Where

A_2 = cross-sectional area of larger diameter capillary 2,
 A_3 = cross-sectional area of the smaller diameter capillary 3.

Where it is desired to produce filaments exhibiting an equality in component distribution (viz, assuming an orifice supplied by two capillaries, the resulting bicomponent filament would exhibit a 50:50 contribution of the constituent streams from each capillary), the flow rate through each capillary supplying a given orifice must equal that of the constituent flows. This may be accomplished by several techniques, all of which function to provide an increase in the flow resistance of the larger capillary to insure an equalization of the mass flow rate with that of the smaller capillary.

For example, in the embodiment illustrated in FIGS. 1-3, such an equality in resistance to flow is accommodated in the spinnerette pack 11, as best depicted in FIG. 1. As there shown, spinnerette pack 11 consists of a circular disc having two annular passageways 13 and 14 interconnected to a polymer source 12, which may be in the form of two discrete fluid-forming mediums, or a single such medium (in the former case, one source would

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supply annular passageway 13 and the other source would supply passageway 14). Assuming a common source, the supply 12 is conveniently forwarded from a conventional spinning source through a conventional gear-type meter pump, neither of which are illustrated.

Annular passageways 13 and 14 divide the single polymer stream into a pair of streams, each of which in turn supply a plurality of capillaries 2 and 3. A filter screen 9 is provided in passageway 13 through which the polymer flows into distribution passageway 4, which latter serves to feed the plurality of smaller cross-sectional area capillaries 3. Annular passageway 14 has disposed therein a fine mesh screen 7 superposed by a small amount of size "A" sand granules, and two additional screens 8 overlying the granules. The screens and sand provide the added resistance to flow required to insure substantial equality in the mass flow rates between each of that group of capillaries supplying a given orifice. The polymer flows through the filter pack into distribution passageway 5 which supplies the plurality of larger cross-sectional area capillaries 2.

The polymer flowing through the aforementioned spinnerette pack 11 and spinnerette 1 is thus divided into two separate groups of streams, each of which is extruded through a plurality of capillary 2 or 3, wherein the linear velocity of the stream passing through capillary 3 is caused to be greater than that passing through larger capillary 2. The polymer streams are caused to combine into a unitary filament in a side-by-side relationship in the vicinity of orifice 16. Subsequent to the extrusion and formation of the filaments, they are drawn away at a higher linear velocity than that of either constituent stream as such streams emanate from orifice 16.

It is to be understood that the embodiment illustrated in FIGS. 1-3 do not require utilization of the spinnerette pack 11 illustrated unless it is desired to process filaments from two discrete melt sources; otherwise, a common melt source may be passed directly through each of the capillaries supplying a given orifice, suitable provision being made for equality in flow resistance of the capillaries where it is desired to produce a filament exhibiting an equality of component distribution.

It will readily be appreciated that the various embodiments of the present construction may be sized to accommodate a wide variation in both linear jet velocity ratio and mass flow rate ratio to provide filaments exhibiting a great variety in jet stretch differential and/or mass ratio of the constituent streams forming a given filament by varying the size and configuration of the capillaries supplying a given orifice according to well known principles of fluid mechanics.

Referring to FIG. 4 of the drawings, in which another embodiment of the invention is shown, reference numeral 17 indicates the spinnerette plate wherein capillaries 20 and 21 are shaped to have different cross-sectional areas and to terminate in a common orifice 22 in the lower spinnerette face 19. Cavities 23 and 24 are provided in the upper face 16 of the spinnerette, both being formed to substantially the same depth to achieve substantially equal length capillaries 20 and 21. Within cavity 24 there is provided a resistance element 25, which may consist of a plurality of screens, sand granules, sintered metal filter elements or the like, such that substantially equal mass flow rates are established in each capillary supplying a given orifice.

Referring to FIG. 5 of the drawings, in which yet another embodiment of the invention is depicted, reference numeral 26 denotes the spinnerette plate through which an enlarged cross section is taken. Formed in the spinnerette are capillaries 29 and 30 having tapered bores. Capillary 29 is formed in the spinnerette plate from face 27 and makes an angle therewith, while capillary 30 is formed therein from face 28 to make substantially the same angle as that of capillary 29 to provide equal length capillaries and substantially equal bores for both capil-

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laries at the respect faces 27 and 28. Such a capillary configuration provides for substantially equal mass flow rates through each capillary and the combined streams emanating from orifice 32 will have different instantaneous linear velocities due to the difference in the cross-sectional areas between the capillaries at their termination in surface 28 of the spinnerette plate.

Referring to FIG. 6 of the drawings, in which still another embodiment of the invention is depicted, reference numeral 33 represents the spinnerette plate through which an enlarged cross section is taken. Disposed in the spinnerette plate are capillaries 36, 37, 38 and 39 with capillaries 36, 39, and 37, 38 having equal cross-sectional areas. The path length of capillaries 36, 39 and 37, 38 are such that there will be substantially equal mass flow rates through each with the fluid streams emanating from capillaries 37, 38 having a higher linear velocity than that of the fluid streams emanating from capillaries 36, 39.

The spinnerette plates depicted in FIGS. 4, 5 and 6 are of such construction that a conventional spinnerette pack may be used therewith in lieu of the pack depicted in FIG. 1 in that the restrictive flow means is incorporated directly within the spinnerette construction per se.

Utilizing the aforementioned apparatus, the production of self-crimping fibers consisting solely of a single polymer is afforded through the mechanism of differential jet-stretch, wherein extrusion of a single polymer is accomplished through two or more converging and unequal area capillaries to impart unequal linear velocities to the streams passing therethrough and the resultant unitary filaments are taken up at a greater linear velocity than that of any constituent stream emanating from a given orifice. The freshly formed filaments are differentially jet-stretched as they issue from their orifices and prior to solidification, with that portion of each filament having the lower linear velocity receiving the greater jet-stretch. This treatment imparts to the constituent zones of the unitary filament different crystalline and shrinkage characteristics which results in the formation of a helical crimp in the filament upon their being relaxed after drawing, optionally followed by inducement of differential shrinkage. Normally, the side of the filament having the higher degree of jet-stretch has the higher percent shrinkage after drawing and is seen to form the inside of the helix of the crimped filaments.

The following example illustrates the use of the apparatus of the invention for the production of permanently crimped filaments which may be formed from polymers of polyethylene terephthalate, polyamide, polyacrylonitrile, polyolefin, polypropylene and the like, as well as blends thereof.

Example

A differential jet-stretch spinnerette and spinnerette pack as depicted in FIG. 1 was placed in the meter pump block of a conventional mono-component melt-spinning machine. Spinnerette plate 1 had formed therein converging pairs of capillaries having 0.062 inch and 0.031 inch diameters. The spinnerette pack 11 contained in passageway 13 two 60 mesh screens 9 which provided filtration media for the fluid stream feeding the smaller diameter capillaries 3; passageway 14 contained one 200 mesh screen 7, approximately one gram of size "A" sand granules 10, and two 60 mesh screens 8 which provided a restricted flow path for the fluid stream passing through the larger diameter capillaries 2.

Polyethylene terephthalate polymer having a specific viscosity (η_{sp}) of 0.40 as determined with 5 grams of polyethylene terephthalate per 100 ml. of solvent consisting of a 2:1 weight mixture of phenol/trichlorophenol at 25° C.

The polymer was melted and extruded at a melt temperature of 275° C., into filaments through the aforementioned spinnerette pack and plate by means of a single meter pump at a pumping rate of 2.5 cc./min.

The following conditions were maintained during spinning:

	0.031-inch Diameter Side	0.062-inch Diameter Side
Linear throughput (ft./min.)	8.4	2.1
Take-up speed (ft./min.)	593	593
Theoretical jet-stretch	70.5	282

The freshly spun and quenched filaments had a differential jet-stretch ratio of approximately 4:1 and were taken up as a unified bundle on a conventional take-up assembly. The filament bundle was subsequently cold-drawn at a draw ratio of 4.6:1 to provide filaments having a tenacity of 4.88 gms./denier, an initial modulus of 82 gms./denier and an ultimate elongation of 19.4%. After cold-drawing, the filaments were observed to contract 70% and had a crimp frequency of 12 crimps per inch in a tension-free state.

In light of the foregoing, it may now be appreciated that there has been herewith disclosed a novel and beneficial apparatus for use in the production of filaments possessing a self-crimping potential, which apparatus involves only simple and easily accomplished modifications of otherwise conventional spinning equipment. By use of such apparatus the technique of converging two or more streams at a differential linear velocity through a common orifice and taking off the resulting filament at a linear velocity greater than any constituent stream velocity is expeditiously facilitated. As will readily be understood, numerous variations and modifications may occur to those skilled in the art appertaining hereto in light of the above teachings. It is, therefore, to be understood that, within the scope of the appended claims, the invention may be practiced otherwise and as specifically described herein.

What is claimed is:
1. A spinning device for use in the production of self-crimping thermoplastic filaments comprising a source of filament-forming material, a spinnerette plate having at least two converging passageways extending therethrough

to merge at a point substantially coincident with a face thereof to define an extrusion orifice supplied by each of said passageways, said passageways being connected to said source and being of different cross-sectional areas at least in the vicinity of said orifice, whereby said filament-forming medium passing from said source through the smaller of said passageways is caused to issue at a greater linear velocity relative to that issuing of said other passageways to provide a filamentary stream having asymmetrically distributed differential in linear velocity over its cross-section.

2. The device of claim 1 wherein those passageways supplying a given orifice are characterized by a substantial equality in mass flow resistance, whereby a filamentary stream issuing from said orifice exhibits a substantial equality of flow contribution from each of said passageways, as measured over the stream cross section.

3. The device of claim 1 wherein the pressure drop between a source of fiber-forming medium and an orifice through one of said passageways is substantially equal to that through the other of said passageways, whereby a filamentary stream issuing from said orifice exhibits a substantial equality of flow contribution from each of said passageways, as measured over the stream cross section.

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WILLIAM J. STEPHENSON, Primary Examiner.