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METHOD OF FORMING FILAMENTS FROM POLYAMIDE AND STYRENE POLYMER MIXTURES

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FIG. 1.

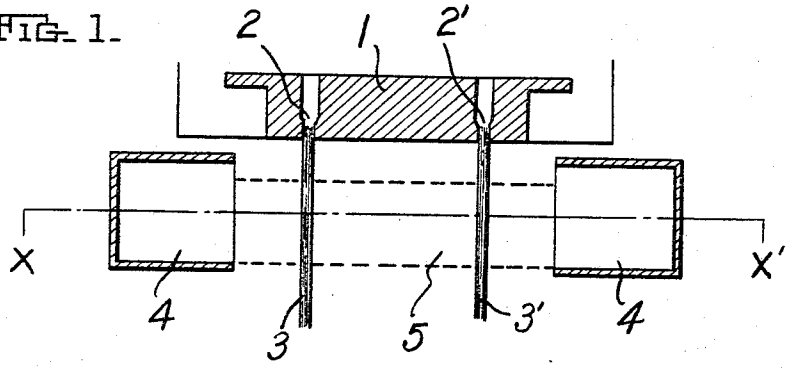
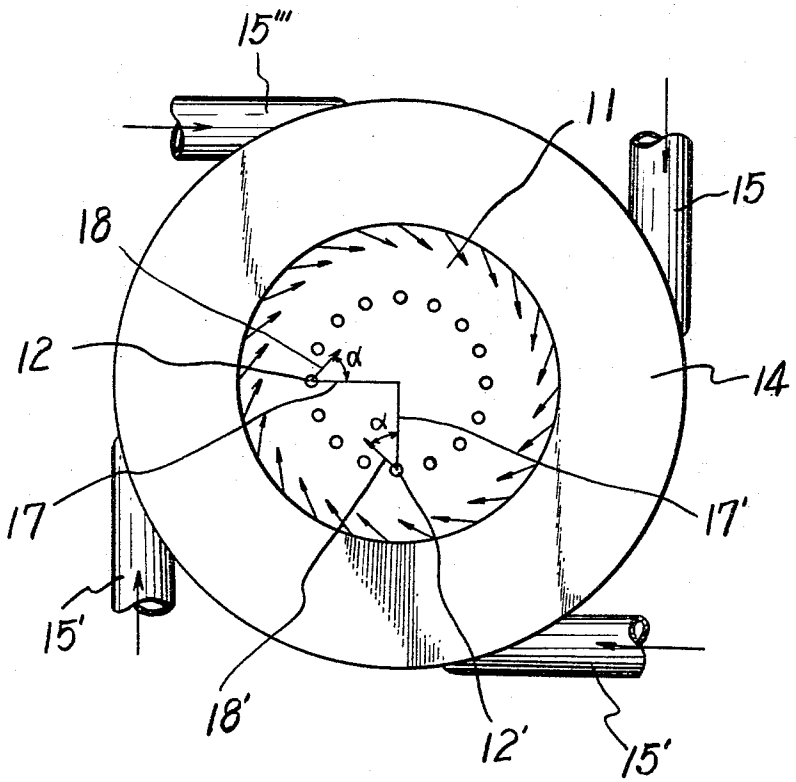


FIG. 2.



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METHOD OF FORMING FILAMENTS FROM POLYAMIDE AND STYRENE POLYMER MIXTURES

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5 Claims. (Cl. 264—210)

This application is a continuation in part of our co-pending application Ser. No. 297,516 "Fibers and Shaped Articles Consisting of Admixture of High Molecular Substances," filed July 25, 1963, and now abandoned.

This invention relates to the improvement of the method for manufacturing filament consisting of the mixture of polyamide and styrene polymer by melt spinning and following two stage drawing.

The first object of the invention is to manufacture filament whose Young's modulus is high.

The second object of the invention is to manufacture filament which is heat set in satisfactory manner.

Another object of the invention is to manufacture filament which can be a material for staple fibers having good spinnability.

Still another object of the invention is to manufacture filamentary material adapted for forming non-woven fabrics or sheets of hollow fibers of polyamide through the extraction of styrene polymer from stable fibers constituting webs, non-woven fabrics, or such webs or fabrics impregnated or coated with a solution or dispersed solution of elastomers such as polyurethane elastomers and then wet coagulated.

While polyamide filament has many desirable physical properties, it is inferior to polyester fibers in the point of heat set because its Young's modulus is low, especially in hot water, and also because it has a hygroscopic property. This difficulty is coupled with rather poor spinnability of staple fibers made therefrom to limit the applications of the polyamide filament as spun yarn.

After a search for a way to overcome these difficulties, we have found that filament of so-called mixture consisting of polyamide and a certain percentage of styrene polymer added thereto presents no such difficulties as above mentioned.

Thus, a feature of our invention lies in the manufacture of polyamide filament containing styrene polymer which alone cannot have good mechanical properties as a filamentary material, in an amount equivalent to 40 to 67 percent based on the weight of filament. This means that the polyamide content in said filament is 60 to 33 percent based on the weight of filament.

The polyamide content should not be either more than 33 percent or less than 60 percent because, if the content of polyamide is less than 33 percent, spinning operation at a maximum spinning rate of 300 m./min. or more will become impracticable with breaking of the filament, as will be clearly seen from Table I, and if the content of polyamide exceeds 60 percent (except for 100%), spinning operation at a maximum spinning rate of 400 m./min. or more will again become infeasible due to breaking of the filament.

TABLE I

6-nylon content	20	30	35	40	50	60	70	80	100
Polystyrene content	80	70	65	60	50	40	30	20	0
Stable max. spinning rate, m./min.	300	300 300	450	600	700	600	400	400	800
Filament breaking rate at max. spinning rate, kg.	35/100	26	3.2	0.9	0.7	0.8	8.5	9.2	0.7
Optimum drawing temp., ° C.	140	150	170	190	190	190	190	190	190
Deg. capable of drawing (times)	2.2	2.8	4.5	5.5	6.0	6.1	6.0	6.2	6.1
After drawing:									
Dry tensile strength, g./d.	1.4	1.7	2.5	3.7	4.8	5.4	6.5	7.3	8.2
Dry elongation, percent	81	73	28	24	23	23	22	20	21
Young's modulus, g./d.	51	50	51	52	51	43	36	32	29
Water absorption, percent	5.8	6.0	6.2	6.4	6.9	8.3	10.4	12.0	12.8
Ratio of residual heat set,[1] percent	Stick	Stick	82	83	81	80	78	65	45
After extraction:									
Hollow ratio, percent	(2)	(2)	65	60	50	38	7	1	0
Tensile strength, g./d.	0.9	1.8	3.1	5.8	6.0	6.2	6.1	6.3	7.9
Elongation, percent	18	3.8	46	30	33	31	26	23	25

[1] The ratio of residual heat set after setting at 160° C. for 3 min. and subsequent immersion in warm water.
[2] Fibrilled.

Unless the content of polyamide departs from the specified range of 33 to 60 percent, spinning operation is made possible at the maximum spinning rate of about 450 m./min. up to about 1000 m./min. If the content of polyamide is less than 33 percent or over 60 percent, spinning at such low velocities as above mentioned will still cause frequent breaking of filament.

Another reason for which the above range is made essential is that a polyamide content of less than 33 percent will bring a relative increase in the content of styrene polymer in the resulting filament, and because of the large content and low softening point of the styrene polymer, said filament tends to develop cohesion among the lengths thereof in the course of subsequent drawing. If the drawing temperature is lowered in order to prevent the cohesion, drawing of the polyamide segment will become practically impossible because of the softening temperature of the segment is much higher than that of the styrene polymer. Accordingly, the filament which results has too low tenacity and too high elongation for practical use. Further because the degree capable of drawing the filament having such content is low, the tenacity of the resulting filament cannot be improved.

Yet another reason for which the above range is regarded critical is that a polyamide content of over 60 percent will limit the effect of the addition of styrene polymer upon improvements of Young's modulus and hygroscopic property of the resulting filament. Further,

if said filament is subjected to a treatment with toluene which is a solvent for styrene polymer in order thereby to extract the styrene polymer contained therein and to prepare hollow filament, said polymer will not be completely extracted off. Therefore, with a polyamide content of over 60 percent, only the filament or fiber having a lower hollow ratio in filament or fiber than the value normally expetced from the content of styrene polymer is obtained. For example, when a filament containing polystyrene as a styrene polymer in an amount of 30 percent based on the weight of filament is treated with toluene, the hollow ratio in said filament should be theoretically about 30%, but is actually about 7 percent, meaning that more than two thirds of the polystyrene remains unextracted in the filament. Presumably responsible for this phenomenon is the fact that, if the content of styrene polymer in filament is as low as 40 percent or less, said polymer will not form a continuous fibril structure in the filament but is dispersed in the polyamide in the form of particles or so-called "islands." This leads to a presumption that the particles of styrene polymer present in the filament are surrounded and enclosed by polyamide, and hence remain unextracted by the solvent. The resulting filament has a low hollow ratio and, due to un-uniform distribution of the styrene polymer in the filament, said filament has inferior mechanical properties. When the content of polyamide is less than 33 percent, the polyamide fails to have a continuous fibril structure in said filament, and becomes unable to maintain the shape of filament if the styrene polymer is extracted with toluene. Hence filament in which the content of polyamide is in the range from 33 to 60 percent of the total amount can be of practical utility for the manufacture of hollow filament or fiber.

In melt spinning of filament in accordance with the invention, both polyamide and styrene polymer may be blended at the specified ratio in the form of pellets, flakes, or powders and then melted and mixed by a screw extruder, kneader, or the like. Alternatively, the polyamide and styrene polymer may be melted separately and then mixed together. A molten mixture thus obtained is spun through nozzle. It is also possible to cool said molten mixture and shape it into pellets, flakes, or powdery form, and then to remelt and spin it. In the latter case, the temperature of the spinning head on the nozzle is preferably kept at a temperature 30 to 90° C. higher than the melting point of the polyamide. Especially when 6-nylon is employed as the polyamide, a temperature in the range from 260 to 300° C. is desired. This temperature range is much higher than the fluidizing temperatures of styrene polymers, e.g., that of polystyrene or polyvinyl toluene, and is also above the spinning temperatures of polyamides. At such elevated temperatures the viscosities of both polymers are lowered sufficiently for melt spinning and mutual fluidity of both polymers is increased sufficiently for spinning.

Another feature of the invention is that, in melt spinning of a mixture consisting of polyamide and styrene polymer of the blended composition as above described, the temperature of quenching zone for the extruded filament in the distance of 20 mm. to 50 mm. from the nozzle surface is regulated to any temperature within the range of 20 to 100° C.

Unlike the case where polyamide or styrene polymer alone is melt spun, said molten resin cannot be directly extruded through a spinneret into the form of filament. If said molten mixture is extruded as it is through a spinneret, it will become a drop as usually formed by a viscous fluid when let fall, but not a continuous filament. This is a unique and troublesome phenomenon which cannot be averted by the use of any molten temperature of said mixture. It occurs only in the course of spinning of the molten mixture in which the mixing ratio of both polymers is substantially same. In melt spinning of either polyamide or styrene polymer alone, no such phenomenon takes place. This phenomenon is believed responsible for the impossibility of manufacturing 2- to 3-denier multifilaments at a spinning velocity of over 400 m./min., though it has been known publicly that about 500- to 2000-denier monofilaments can be made at a low spinning velocity of 40–100 m./min. from molten mixtures consisting of substantially the same amounts of two types of polymers.

In order to preclude such phenomenon, we made diversified studies. As the result, we have succeeded in preventing the occurrence of such phenomenon by injecting a cooling medium, e.g., air or nitrogen gas, having a velocity of about 4 m./sec., to the filament just extruded from the nozzle surface to thereby regulate the temperature of the quenching zone at a distance of 20 to 50 mm. from the nozzle surface to a range from 100° down to 20° C. In this case the injection velocity of the cooling medium is more than ten times as high as that of the cooling medium usually employed for cooling of melt spun filament. If the injection velocity of the cooling medium is less than 4 m./sec., the filament will break so often that a steady spinning operation will be made impossible, though any dropping phenomenon will be averted. By way of example, the relations among the injection velocity of cooling air, the temperature of quenching zone, and spinnability in spinning of a molten mixture consisting of 55 percent by weight of 6-nylon (polycaprolactam) and 45 percent by weight of polystyrene are given in Table II.

TABLE II

Injection velocity of air	Temperature of the quenching zone,[1] ° C. Distance from the nozzle surface					Spinnability
	10 mm.	20 mm.	40 mm.	60 mm.	100 mm.	
0 m./sec.	170	150	125	90	50	Drop is formed and no filament results.
0.4 m./sec.	162	143	116	82	44	Filament is produced but it breaks so often that it cannot be taken up on reel.
4 m./sec.	80	55	35	32	30	Filament is produced at a rate of 400 m./min.

[1] Temperature determined at a point 5 mm. apart outwardly from each filament specimen.

In injecting a cooling medium to the extruded filament, it is further important that a direction of injected medium should be regulated so that the horizontal segment of an injected cooling medium comes within a range of angles from 40 to 90° with respect to the "center line." The term "center line" as herein used means a straight line extending from the nozzle center to the nozzle holes arranged concentrically of the nozzle. Therefore, in the case where the horizontal segment is at an angle of 90° to the center line, the cooling medium is blown along a circumference defined by the nozzle holes disposed concentrically of the nozzle. The stream of cooling medium is thus enabled to form an eddy current from the outside toward the center in the quenching zone beneath the nozzle surface. As the stream is so directed as to form

an eddy current, the velocity of cooling medium is made substantially uniform in said quenching zone, and all the lengths of filament on the circumference can be uniformly cooled. For this reason it is desirable in the spinning of filament according to the invention to use a nozzle provided with holes concentrically on the circumference of the nozzle surface. If the cooling medium is injected in the direction where the center line and the direction of injected cooling medium form an angle of 0°, as in the conventional method for cooling melt spun filament, or in the direction from the outside of the quenching zone toward the center, the injection velocity of cooling medium becomes so high that a turbulent flow is produced in the quenching zone, which in turn causes uneven cooling of the individual filaments and frequent occurrence of filament breaking with a consequent decrease in spinnability. For example, in cooling a filament consisting of the mixture of 55 percent by weight of 6-nylon and 45 percent by weight of polystyrene extruded at a spinning velocity of 650 m./min., with air at 20° C. and supplied at a blowing velocity of 5.5 m./sec. in the quenching zone, the angle defined by the direction of a horizontal segment of the blown air and the center line is varied in many ways. Such variations in the angle are related with resultant frequencies of filament breaking in Table III.

TABLE III

Angle formed by cooling air and center line, degrees	0	30	60	75	90
Frequency of breaking per 100 kgs. of filament	74	31	2.0	0.5	0.7

The device to supply the cooling medium is arranged outside of the quenching zone and has a blowing hole at a distance of from 10 to 50 mm. from the nozzle surface. The blowing hole may be covered with a perforated plate or net or may take the form of a slit. It must be carefully disposed so that the cooling medium can be supplied in the horizontal direction with respect to the nozzle hole. Also, the blowing hole must be kept at a distance of more than 10 mm. in the running direction of filament from the nozzle surface. If the distance is less than 10 mm., the extruded filament is cooled too quickly for smooth drafting thereafter, and invites an increase in the number of filament break-down. If the distance exceeds 50 mm., on the other hand, the filament is cooled so slowly that it forms a drop.

The cooling medium for use in the invention may be any fluid which will not chemically react with the extruded filament. Usually, air, nitrogen gas, carbon dioxide gas, water vapor, etc. are useful for this purpose.

The invention will be further described with reference to the accompanying drawings, wherein:

FIG. 1 is a diagrammatic sectional view of the nozzle with cooling hood; and

FIG. 2 is a plan view taken along the line X–X′ of FIG. 1.

Referring now more particularly to the drawings, in FIG. 1 there is shown a nozzle **1** having holes **2**, **2′**, . . . of 0.2 mm. dia., for instance. The extruded filaments **3**, **3′**, . . . are cooled at the quenching zone **5**, having a distance of 20 mm. to 50 mm. from the nozzle surface, by cooled air steam which is supplied from cooling hood **4**. Said quenching zone **5** is surrounded by cooling hood **4** which is positioned at the distance of 10 mm. to 50 mm. from the nozzle surface. As shown in FIG. 2, air streams **18**, **18′**, . . . are blown in to the direction having the angle of the range from 40 to 90° to the center lines **17**, **17′**, . . . which are the straight line extending from the nozzle center to nozzle holes **12**, **12′**, ... There are used pipes **15**, **15′**, **15″**, and **15‴**, which are not shown in FIG. 1, to supply cooling medium to cooling hood **14**.

The third feature of the invention is that the extruded filament consisting of the mixture of polyamide and styrene polymer is subjected to the first stage drawing to a length 2 to six times greater than the initial length at a temperature between 160° and 180° C., and then to the second stage drawing to a length 1.2 to 3 times greater than the filament length after the first stage drawing, at a temperature in the range above 165° C. but below the temperature (about 230° C.) lower by 5° C. than the melting point of the polyamide and still higher by more than 5° C. than the temperature used for the first stage drawing. While polyamide filament is capable of being drawn at temperatures above room temperature to form filament having great tenacity, the filament of the present invention cannot be drawn unless the temperature condition is above 160° C. because it contains styrene polymer. To obtain a high tenacity filament through a further drawing stage, the additional drawing must be performed at such a temperature that will completely melt and fluidize the styrene polymer in the filament, that is, at a temperature above 170° C. It must be noted, however, that breaking of the filament will develop unless the drawing temperature is regulated to a temperature lower by 5° C. than the melting point of polyamide contained in the filament. At a drawing temperature above 170° C. styrene polymer becomes fluid and serves as a plasticizer for polyamide. By dint of this, such high drawing temperature greatly facilitates the drawing of the filament of the present invention. As the filament of the present invention tends to lose its transparency upon one stage drawing, it is advisable to carry out multi-stage drawing. For example, two stage drawing conveniently gives a filament having good transparency. Total elongation of filament made of a mixture consisting of 50 percent by weight of 6-nylon and 50 percent by weight of polystyrene after one stage drawing and two stage drawing, and the effects of such drawing processes upon the transparency of filament are shown in Table IV. As can be seen from the table, two stage drawing brings greater total elongation than that by one stage drawing and permits the transparency of filaments to be maintained until the filament is drawn to an even higher extent.

Useful media for heat drawing of filament under the invention include air, nitrogen, carbon dioxide gas and other gases, organic solvents, fused metals. Metallic surfaces and pins also may be employed. If necessary,

TABLE IV

Drawing temp.	Total elong.	Denier size	Dry tens. strength, g./d.	Dry elong.	Transparency
One stage drawing at 295° C.	4.0	3.20	38	70.0	Transparent.
	5.0	2.70	4.3	37.5	Do.
	5.5	2.42	4.6	22.6	Translucent.
	5.75	7.31	4.8	20.9	Opaque.
	6.0	Broken			
One stage drawing at 175° C. (3-times) and Two stage drawing at 205° C.	4.0	3.40	4.0	65.3	Transparent.
	5.0	2.75	4.7	23.0	Do.
	5.5	2.40	5.0	21.2	Do.
	6.0	2.08	6.0	17.5	Do.
	6.5	1.92	6.5	16.0	Do.
	7.0	1.70	6.8	15.0	Opaque.
	7.5	Broken			

the drawn filament may be subjected to heat shrinking treatment.

Polyamides useful in the practice of the invention include 6-nylon, 6.6-nylon, 7-nylon, 11-nylon, and other polyamides. Co-condensates formed essentially of polyamides, for example polymers containing principally amide group and, to lesser extents, ether group, ester group, urea group, and the like in the molecule, may also be adopted.

Styrene polymers which may be used in the invention include styrene, vinyl toluene, chlorostyrene, dichlorostyrene, acenaphthene, α-methyl styrene, and other homopolymers or their copolymers or their sulfonated products.

Of many possible combinations of these polymers, those consisting of 6-nylon or 6.6-nylon as the polyamide and polystyrene as the styrene polymer give the best results on account of the compatibility of component polymers and spinnability and drawability of the resulting filament. The filaments made from these combinations are highly tenacious and are obtained at low cost.

Now the invention is illustrated more fully by the following examples, in which all the parts are by weight unless otherwise specified.

Example 1

Sixty parts of polyamide (6.6-nylon) chips and 40 parts of polystyrene (with a polymerization degree of 2500) were mixed, fed into a screw-extruder heated at 290° C., and melted and homogenized in the machine. The melt was spun through a nozzle having 300 holes, each 0.25 mm. in diameter, at a spinning temperature of 300° C. and a productivity of this nozzle amounting to 300 g./min., with subsequent cooling with air injected into the quenching zone as tabled hereunder. In the table are also given the conditions of quenching zone not cooled as above and the maximum spinning rate of the filaments.

Temp. measuring point (Distance from nozzle surface)	Temperatures of quenching zone, ° C.				Max. spinning rate
	2 cm.	3 cm.	5 cm.	7 cm.	
Temp. of quenching zone:					
(Without cooling)	170	140	120	90	Not spinnable.
(With cooling	96	80	60	45	900 m./min.

As will be apparent from the above table, cooling of the drawing zone to a temperature below 100° C. gave a very favorable effect upon the spinnability and made it possible to carry out the spinning in most stabilized manner.

Said filaments were drawn 3.5 times greater than the initial length in air at 165° C. and was further drawn two-times greater than the length after the first stage drawing in air at 205° C. The filaments thus produced have good transparency, a tensile strength of 6 g./d., elongation of 22%, and Young's modulus of 60 g./d.

Example 2

A mixture of 50% of 6-nylon chips and the same amount of polystyrene (with a polymerization degree of 2600) chips was fed, melted and homogenized in a screw-extruder heated at 290° C., and the melt thus prepared was spun through a nozzle, 160 mm. in outside diameter and which had 300 holes in two rows, each hole being 0.25 mm. in diameter, at a spinning temperature of 280° C. Below the spinning head, a cooling medium supply device having ring pattern, 240 mm. in inside diameter and 340 mm. in outside diameter, was placed in such a manner that the top end of the opening of said device for blowing cooling medium was disposed at a distance of 20 mm. downward from the nozzle surface. From a circular cooling head, 20 mm. in width, provided inwardly of the device, air was blown through a net screen in the direction at an angle of 70° to the center line, at a velocity of 5 m./sec. The filament spun at the nozzle surface was drafted and then cooled by the cooling air. The spinning was accomplished at a spinning rate of 600 m./min. in very stable manner. The atmospheric temperature at the point 5 mm. outward from the outermost lengths of filament 30 mm. below the nozzle surface was 45° C.

Said filaments were drawn four-times greater than the initial length in air at 160° C. and was further drawn 1.6-times greater than the length after the first stage drawing in air at 200° C. The filaments thus obtained were highly transparent, and yet possessed a tensile strength of 6.2 g./d., elongation of 18.5%, and Young's modulus of 55 g./d.

Example 3

A mixture of 40% of 6-nylon chips and 60% of polystyrene chips was fed, melted and homogenized in a screw-extruder heated at 300° C., and the melt thus prepared was spun through a nozzle, 170 mm. in outside diameter and which had 400 holes in three rows, each hole being 0.2 mm. in diameter, at a spinning temperature of 290° C. Below the spinning head a cooling medium supply device having ring pattern, 260 mm. in inside diameter and 380 mm. in outside diameter, was placed in such a manner that the top end of the opening of said device for blowing cooling medium was disposed at a distance of 30 mm. downward from the nozzle surface. From a circular cooling head, 30 mm. in width, provided inwardly of the device, nitrogen gas was injected through a perforated plate having four holes, 3 mm. in diameter, per square centimeter of the plate, in the direction at an angle of 60° to the center line, at a velocity of 6 m./sec. The filament spun at the nozzle surface was drafted and then cooled by the cooling gas. The spinning was accomplished at a spinning rate of 500 m./min. in very stable manner, and 12-denier monofilament was obtained. The atmospheric temperature at the point 5 mm. outward from the lengths of filament in the outermost layer 40 mm. below the nozzle surface was 40° C. The filaments thus obtained were drawn to a length 4.9 times greater than the initial length in hot air at 180° C. and were further drawn 1.2 times than the length after the first drawing in hot air at 195° C. The drawn filaments have dry tensile strength of 3.5 g./d., dry elongation of 40%, and Young's modulus of 40 g./d.

Example 4

Fifty-five parts of 6.6-nylon chips and 45 parts of chips of a copolymer consisting of 10 mol. percent of α-methyl styrene and 90 mol. percent of styrene were mixed and fed in a screw-extruder heated at 310° C. The mixture was melted and homogenized therein and was spun through a nozzle, 170 mm. in outside diameter and which had 350 holes in two rows, each hole being 0.3 mm. in diameter, at a spinning temperature of 300° C. Below the spinning head a cooling medium supply device having ring pattern, 250 mm. in inside diameter and 370 mm.

in outside diameter, was placed in such a manner that the top end of the opening of said device for blowing cooling medium was disposed at a distance of 25 mm. downward from the nozzle surface. From a circular cooling head, 40 mm. in width, provided inwardly of the device, air was blown through a net screen in the direction at an angle of 80° to the center line, at a velocity of 7 m./sec. The filament spun at the nozzle surface was drafted and then cooled by the cooling medium, and the spinning was accomplished at a spinning rate of 500 m./min. in very stable manner. The filaments thus obtained were drawn to a length 4.5 times greater than the initial length in hot air at 180° C. and were further drawn 1.2 times than the length after the first drawing in hot air at 210° C. The drawn filaments have dry tensile strength of 4.1 g./d., dry elongation of 35%, and Young's modulus of 50 g./d.

Example 5

Sixty parts of 6-nylon and 40 parts of vinyl toluene chips were mixed, fed in a 40 mm., screw-extruder, and melted and homogenized therein at 290° C. The melt was then extruded in air through a nozzle having 400 holes, each 0.3 mm. in diameter, at the condition described in Example 1, and wound up at a rate of 600 m./min. The filaments, thus obtained were drawn four-times greater than the initial length in hot air at 170° C. and further drawn 1.2-times greater than the length after the first stage drawing in hot air at 180° C. Said filaments have dry tensile strength of 3.5 g./d., dry elongation of 28% and Young's modulus of 52 g./d.

We claim:

1. In the method of manufacturing filament from a mixture of polyamide and styrene polymer by melt spinning and subsequent two stage drawing, the improvement which comprises:

(a) melting a mixture consisting of polyamide in an amount of 33 to 60 percent based on the weight of said mixture and styrene polymer in an amount of 67 to 40 percent based on the weight of said mixture;

(b) extruding the melting through a nozzle into the form of filament, said nozzle having holes in a concentric arrangement;

(c) cooling said filament in a quenching zone disposed within a distance range of 20 to 50 mm. from the nozzle surface, said quenching zone being cooled to any temperature within the range of 100 to 20° C. by the injection of a stream of cooling medium having an angle of 40 to 90° to the center line connecting the nozzle center and nozzle holes in the horizontal direction and having line velocity of more than 4 m./min.; and thereafter

(d) subjecting said filament to first stage drawing at a temperature in the range from 160° to 180° C. to a length 2 to 6 times greater than the initial length of said filament and then to second stage drawing at a temperature in the range from 165° to 230° C. and also higher than the first stage drawing temperature by more than 5° C. to a length 1.2 to 3 times greater than the length after the first stage drawing.

2. The process of claim 1 in which polyamide is a member selected from the group consisting of 6-nylon, 6.6-nylon, 7-nylon and 11-nylon.

3. The process of claim 1 in which styrene polymer is a member selected from the group consisting of homopolymer and copolymer of styrene, vinyl toluene chlorostyrene, dichloro styrene, acenaphthylene and α-methylstyrene.

4. The process of claim 1 in which polyamide is 6-nylon, and styrene polymer is polystyrene.

5. The process of claim 1 in which polyamide is 6.6-nylon, and styrene polymer is polystyrene.

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