Sept. 21, 1971 TATSUKI MATSUO ET AL 3,606,689

APPARATUS FOR HEAT TREATMENT OF FILAMENT

Filed Feb. 20, 1969 2 Sheets-Sheet 1

FIG.1

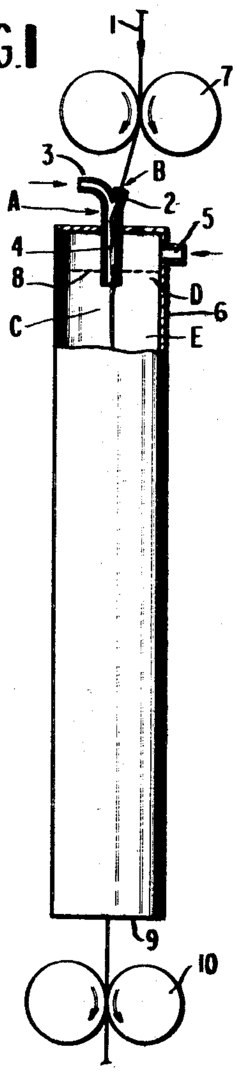


FIG.2

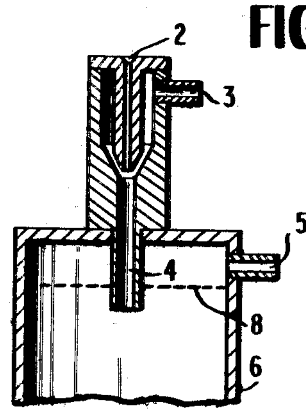
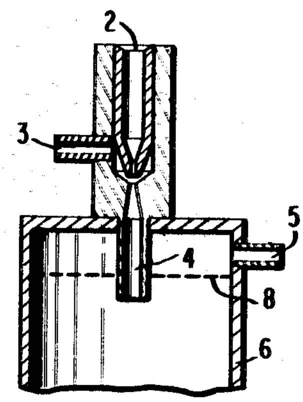


FIG.3



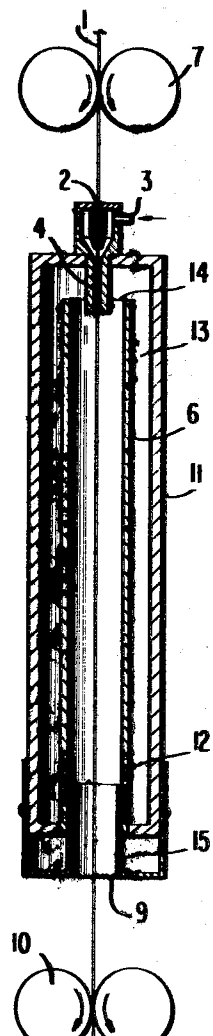


FIG.5

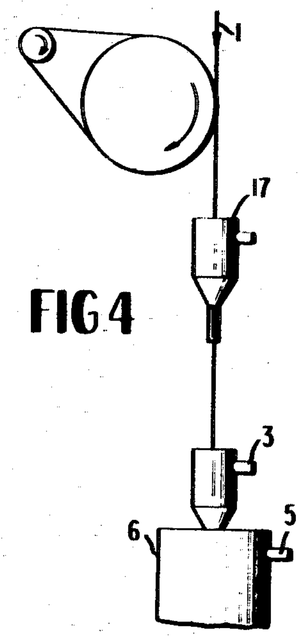


FIG.4

INVENTORS
TATSUKI MATSUO
TAKASHI FUKUDA
SHOSUKE NANRI
KATSUYA ISHITOBI
RYUNOSUKE MASUDA
HIROSHI OKANO

BY *Craig, Antonelli, Stewart and Hill* ATTORNEYS

APPARATUS FOR HEAT TREATMENT OF FILAMENT

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FIG.6

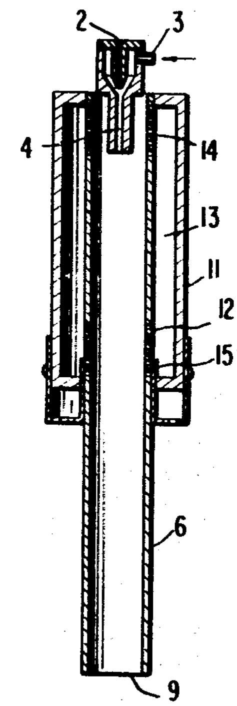


FIG.7

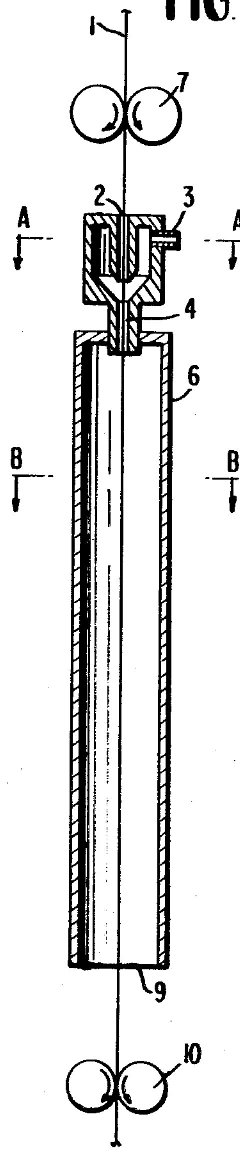


FIG.8

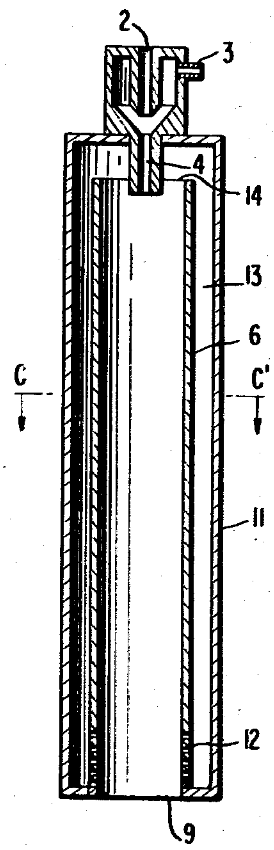


FIG.9

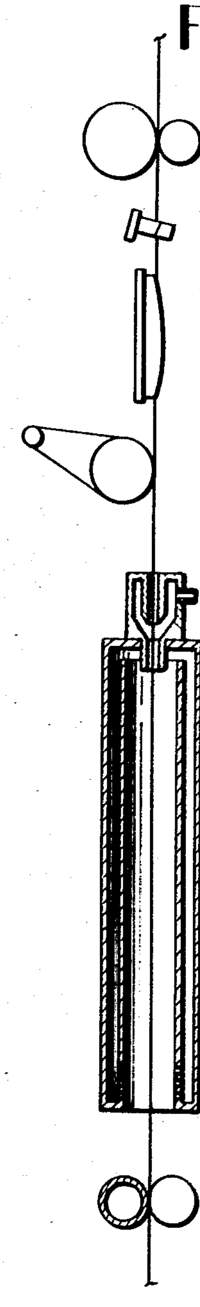


FIG.10

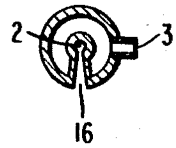


FIG.11

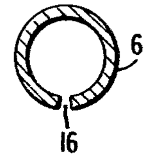
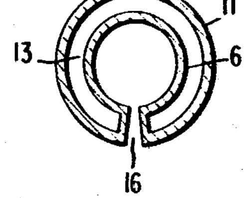


FIG.12



INVENTORS
TATSUKI MATSUO
TAKASHI FUKUDA
SHOSUKE NANRI
KATSUYA ISHITOBI
RYUNOSUKE MASUDA
HIROSHI OKANO

Craig, Antonelli,
BY Stewart & Hill ATTORNEYS

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APPARATUS FOR HEAT TREATMENT OF FILAMENT

Tatsuki Matsuo, Takashi Fukuda, Shosuke Nanri, Katsuya Ishitobi, Ryunosuke Masuda, and Hiroshi Okano, Otsu-shi, Japan, assignors to Toyo Boseki Kabushiki Kaisha, Osaka-shi, Osaka-fu, Japan

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Int. Cl. F26b *13/10*

U.S. Cl. 34—155 6 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus for treatment of filament in the relaxed state with hot gas stream which comprises a heating cylinder, an inlet portion for the filament provided at one end of the cylinder, an outlet for the filament provided at the other end, and an inlet for a secondary gas stream provided near the inlet portion, the filament being joined by the primary gas stream at the inlet portion and then introduced through the inlet portion into the cylinder. By the use of such apparatus, a filament can be heat-treated in the relaxed state at a high efficiency of operation.

The present invention relates to an apparatus for the heat treatment of a filament, particularly to an apparatus for heat treating a filament efficiently in the relaxed state with a prevention from becoming entangled in a filament feeding roller and being ruffled under the influence of a turbulent flow.

Hitherto, there have been proposed a variety of methods and apparatuses for the heat treatment of a filament in the relaxed state. Thus, heat treatment is carried out, for instance, for the formation of crimps in a synthetic fiber yarn having a latent crimping ability, secondary treatment of a yarn crimped by false twisting, thermal shrinkage of a spun yarn or multifilament constituted with filaments having different thermal shrinkage properties to produce a bulky yarn, thermal setting of relaxation of stretched filament to improve the dimensional stability or the like.

The conventional heat treatment is largely carried out in such a manner that the filament is made in hank or placed on a net and then subjected to the treatment. In view of the production efficiency and facilities, however, it is favorable that the filament is continuously fed through a feeding roller to an apparatus for heat treatment and, while permitting to shrink, taken up at a rate slower than the feeding rate. In this case, the following problems arise:

(a) The filament is apt to entangle in a feeding roller when fed through the feeding roller under a slight tension, resulting in the instability in respect of filament feeding;

(b) While feeding the filament in the relaxed state through a heating zone is requisite, it is quite difficult to proceed with such operation at a high feeding efficiency in a simple manner;

(c) The filament in the relaxed state can not be heat-treated with a high efficiency, although it is improved by bringing the filament under a tension into close contact with a heating plate;

(d) In a conventional method for heat treatment of a filament in the relaxed state with a gas stream in a heating cylinder, the gas stream is apt to cause a temporary low pressure region in the cylinder so that air-eddies occur near the inner peripheral wall to cause entangling of the filament and sometimes a bundle of filament to remain therein.

The present invention is directed to overcome these drawbacks in the known methods and apparatuses.

According to the present invention, there is provided an apparatus for treatment of the filament in the relaxed state with a hot gas stream which comprises a heating cylinder, an inlet portion for the filament provided at one end of the cylinder, an outlet for the filament provided at the other end, and an inlet for a secondary gas stream provided near the inlet portion, the filament being joined by primary gas stream at the inlet portion and then introduced through the inlet portion into the cylinder.

Such apparatus can be embodied in a variety of specific constructions, some of which are as follows:

(1) In such apparatus, the inlet for the secondary gas stream is so constructed that the secondary gas stream is supplied with autogenic or elevated pressure from a separate secondary gas stream supplier;

(2) In such apparatus, the heating cylinder is constructed surrounded by a jacket having an upper port near a filament inlet in the inlet portion for the filament and a lower port at an appropriate position lower than the filament inlet, and the hot gas stream is introduced from an optional position lower than the filament inlet into the jacket and circulated through the upper port into the heating cylinder;

(3) In such apparatus, the inlet for the secondary gas stream is formed in a narrow slit provided in the direction of the filament over the whole length of the inlet portion for the filament and the heating cylinder;

(4) In such apparatus as stated in the above (1) or (2), a narrow slit is provided in the direction of the filament over the whole length of the apparatus.

Examples of the structure of the inlet portion, through which secondary gas stream is introduced into the heating cylinder, are as follows:

(1′) A structure wherein an independent secondary gas stream supplier is provided and gas stream is supplied with autogenic or elevated pressure from the circumference of the filament inlet (as shown in FIGS. 1, 2 and 3);

(2′) A structure wherein a gas stream suction port is provided at an appropriate position of the heating cylinder lower than the filament inlet and the port of a naturally circulating gas inlet, i.e. an inlet for secondary gas stream, connected to the suction port is provided near the filament inlet (as shown in FIGS. 5 and 6);

(3′) A structure wherein a slit, through the filament can be fed or applied, is provided as the secondary gas stream inlet at the filament inlet and the heating cylinder (as shown in FIG. 7);

(4′) A structure wherein a slit, through which the filament can be fed, is provided at the filament inlet and the heating cylinder in the direction of the filament, the cylinder having a gas stream suction port at an appropriate position lower than the filament inlet and the port of a naturally circulating gas inlet connected to the suction port around the filament (as shown in FIG. 8).

In the above structure (3′) and (4′), the slit may be opened when the filament is fed or applied thereto and closed by a lid except at the place near the filament inlet during operation.

The secondary gas stream inlet may be provided in one or more slits, annular holes, round holes or the like.

These and other objects, features and advantages of the present invention will become more obvious from the following description when taken with the accompanying drawing which shows, for purposes of illustration only, several embodiments of the present invention, and wherein;

FIG. 1 is an elevational view, partly in cross-section of one embodiment of a filament heat-treatment apparatus in accordance with the present invention.

FIGS. 2 and 3 are partial cross-sectional views, on an enlarged scale, illustrating two modified embodiments of the head portion for the heat treatment apparatus of FIG. 1.

FIG. 4 is a partial schematic elevational view of a modified heat-treatment apparatus according to the present invention with an auxiliary unit providing a filament suction.

FIGS. 5 and 6 are longitudinal axial cross-sectional views of two further modified embodiments of a filament heat-treatment apparatus in accordance with the present invention with a naturally circulating secondary gas stream.

FIGS. 7, 8 and 9 are axial longitudinal cross-sectional views through three different embodiments of a filament heat-treatment apparatus in accordance with the present invention provided with slits for the admission of a secondary gas stream, and

FIGS. 10, 11 and 12 are cross-sectional views taken, respectively, along line A–A′ of FIG. 7, line B–B′ of FIG. 7 and line C–C′ of FIG. 8.

The present invention will be fully described in the following description referring to the attached drawings wherein **1** is a filament before heat-treatment, **2** is a filament feeding inlet, **3** is a primary hot gas supply port, **4** is a filament inlet (a primary hot gas inlet), **5** is a secondary gas supply port, **6** is a heating cylinder, **7** is a pair of feeding rollers, **8** is a rectifying plate, **9** is a filament outlet, **10** is a pair of take-up rollers, **11** (FIGS. 5, 6 and 8) is a jacket, **12** is a secondary gas suction port, **13** is a circulation area, **14** is a natural circulation gas (secondary gas) supply port, **15** is a gas flow regulating plate and **16** (FIGS. 10–12) is a slit.

Referring now to FIG. 1, the heating cylinder **6** is provided with a heater (not shown) on the inner surface. The filament **1** is fed through a pair of feeding rollers **7** to the filament feeding inlet **2**. Primary hot gas stream is introduced from the primary hot gas supply port **3**, joins with the filament **1** at the portion A, transports the filament at the portion B to the direction of the portion C and is conducted through the filament inlet **4** into the heating cylinder. At the portion C, the filament **1** is ejected into the heating cylinder by the primary hot gas stream. In the heating cylinder, the primary hot gas stream is combined with the secondary gas stream and transports the filament smoothly during which a heat treatment of the filament in the relaxed state is accomplished. The filament is continuously introduced into the heating cylinder and, after heat treatment, taken out from the outlet **9** by means of the take-up rollers **10**. In the apparatus as shown in FIG. 1, the hot gas stream is also discharged from the outlet **9**.

Other embodiments of the head portion consisting of a filament feeding inlet **2**, a primary hot gas supply port **3**, a secondary gas supply port **5** and an upper portion of the heating cylinder **6** are shown in FIGS. 2 and 3. Except for the illustrated modifications, they are constructed in the same manner as the one shown in FIG. 1.

Embodiments of the apparatus for the use of a naturally circulating gas stream as the secondary gas stream are shown in FIGS. 5 and 6 wherein filament proceeds as in FIG. 1. The primary hot gas stream is introduced through the primary hot gas supply port **3**, joins with the filament **1** and is then conducted to the heating cylinder **6**. The hot gas stream flows down along in the direction of the filament and is partly discharged from the filament outlet **9**. The remaining portion of the hot gas stream is naturally sucked through the secondary hot gas stream suction ports **12**, flows through the circulation area **13** between the heating cylinder **6** and the jacket **11** and is recycled as a secondary gas stream into the heating cylinder **6** through the natural circulation gas supply port **14** opened near the filament inlet **4**. At the secondary gas suction port **12**, a gas flow regulating plate **15** is provided so as to regulate constantly the amount of flow of the secondary gas stream.

Embodiments of the apparatus in which the whole or part of a secondary gas stream is introduced through a slit are shown in FIGS. 7, 8 and 9. The cross sectional views taken along line A–A′ in FIG. 7, along line B–B′ in FIG. 7 and at C–C′ in FIG. 8 are shown in FIGS. 10, 11 and 12, respectively. The filament proceeds as in FIG. 1. The primary hot gas stream is introduced through the primary hot gas supply port **3**, joins with the filament **1** and is then led to the heating cylinder **6**. The whole or part of secondary gas stream is introduced through the slit **16** (shown in FIGS. 10, 11 and 12), which is conveniently available for supplying or feeding the filament to the apparatus therethrough. The slit may be narrow and is, for instance, preferably formed about 0.1 to 1.0 mm. wide for the treatment of filaments of 150 deniers. The role of the circulation area **13** in FIGS. 8 and 9 is entirely the same as that in FIGS. 5 and 6.

In the apparatus of the present invention, the cross section of the heating cylinder **6** is provided sufficiently larger than that of the primary gas supply port **3** and the flow amounts of the secondary gas stream and of the primary gas stream are controlled so as to reduce the flow velocity of the gas stream in the cylinder **6** and thereby to keep the filament in the relaxed state. In the case of lack of the secondary gas stream, it will become extremely difficult to smoothly transport the filament through the cylinder. In other words, the temporary pressure reduction may occur at the portion D shown in FIG. 1 through the action of the primary gas stream with the development of air eddies at the portion E near the inner peripheral wall of the cylinder. The development of air eddies therein may cause the filament to flow backward and then to stay around an end portion of the filament feeding inlet so that the filament is not smoothly transported through the cylinder. When the flow amount of the secondary gas stream is excessive, the filament can be smoothly transported through the cylinder. For keeping the filament in the relaxed state, however, the flow amounts of the primary and secondary gas streams must be suitably regulated. In view of the fact that the secondary gas stream is provided for the improvement of the heating efficiency on the filament in order to remove the uneveness of the heating effects, it is preferable to heat the secondary hot gas substantially up to the temperature equal to the primary gas stream or the peripheral wall of the cylinder, before the operation takes place. For this reason, the secondary hot gas stream is practically favored to successively circulate through the cylinder in a manner that the hot gas introduced is sucked out of the cylinder at an optional position about an end portion thereof, as shown in FIGS. 5, 6, 8 and 9. In this case, the hot gas stream flowing through the heating cylinder is the sum of the circulation gas stream and a gas to be supplied together with the filament. The apparatus as herein described does not only create turbulent flow in the neighborhood of the filament feeding inlet but also is effective to reduce the amount of hot gas stream to be supplied, thereby saving the cost of production, and because the amount of hot gas stream in the heating cylinder is great, the heat treatment effect of the gas current on the filament increases.

As described above, the apparatus (embodied in FIGS. 5, 6, 8 and 9) in which the secondary hot gas stream is formed by natural circulation is of particular favor by reason of the simplicity of structure, the efficient utilization of heat and the high efficiency of heat treatment.

A typical example of the jacket in the present invention (embodied in FIGS. 5 and 6) is so constructed as surrounding the heating cylinder. As a matter of course, it may be constructed in any other form as long as the secondary gas stream naturally sucked from the lower position of the heating cylinder is circulated into the heating cylinder at the position near the filament feeding inlet.

In the apparatus where a gas stream is introduced through a slit, the application or feel of the filament to the apparatus can be advantageously effected with facility.

The apparatus having the advantageous structures as stated above is shown in FIGS. 8 and 9.

An introduction portion of both filament and the primary hot gas may be arranged in any forms, for example, the form as shown in FIG. 1 in which the filament rides in the hot gas to be introduced from one side thereof, or the forms as shown in FIGS. 2 and 3 in which the hot gas introduced flows into the cylinder while surrounding the filament.

The pneumatic pressure of the primary hot gas may be normally below 2 kg./cm.^{2} (gauge pressure) preferably below 0.5 kg./cm.^{2} for the operational condition. And, the flow amount per each filament is usually above 10 ml./sec. (preferably 50 ml./sec.) and below 4,000 ml./sec.

The temperature of the heating cylinder is widely varied with the kind of the filament to be heat-treated and may be usually from about 70 to about 250° C. The temperatures of the primary gas stream and of the secondary gas stream are ordinarily from about 70 to about 250° C. and from room temperature to about 250° C., respectively.

The cross section of the heating cylinder should be sufficiently larger, preferably not less than 4 times larger and particularly more than 10 times and less than 200 times larger, than that of the introduction portion of both filament and the primary hot gas in size such as diameter or side.

The length of the cylinder should be determined in consideration of the period for the filament to remain therein and the heat-treating maturity for the filament to thermal-shrink, said period being adjusted longer than said heat-treating maturity. It is practically estimated at least 15 cm., preferably more than 30 cm. and less than 2 m.

The filament fed through the cylinder may be constructively taken up by means of take-up rollers as shown in FIGS. 1, 5 and 9. Alternatively, the filament may be wound up after it is thrown off on a movable tool such as wire net. In the case where take-up rollers are provided, the filament on one hand is fed through the cylinder by means of the gas stream and on the other hand taken up thereby. In any cases, the filament feeding velocity should be higher than the take-up velocity of the rollers or the discharging velocity of the gas stream.

Again, in the case where the take-up rollers are provided, it brings the advantage that the shrinkage of the filament in the lengthwise direction (including the shrinkage of the apparent length due to crimp formation) can be regulated by selecting the rate between the feeding velocity and the take-up velocity.

The apparatus of the present invention can be applied to various processes of thermal treatment in the textile industry, for example, in the process of secondary setting of textured multifilament, in the process of thermal setting for the purpose of the shrinkage reduction in filament, in the process of bulking through thermal shrinkage spun yarn or multifilament constituted with fibers having different thermal shrinkage properties, or in the process of the crimp formation on fiber yarns, such as bicomponent filament yarn as their representative, having latent crimping ability. Especially, the apparatus of the present invention can be suitable for the crimp formation on fiber yarn having the latent crimping ability. In this case, the filament should be in the highly relaxed state and should be heat-treated under the extremely low tension, as the case may be, in the range of 1×10^{-4} to 1×10^{-5} mg./d. If the fiber yarn having latent crimping ability is multifilament, although originally filaments should be separated into a single filament before the heat treatment is applied thereto, the apparatus of the present invention does not necessarily require such a step because the separating operation takes place while the filament is transported through the heating cylinder together with the hot gas stream. In view of this, the apparatus of the present invention can be suitable for the crimp formation also on multifilaments having a latent crimping ability.

As the hot gas heretofore described for the present invention, either air, vapor or mixture of air and vapor can be used. However, in any case where the filament should be completely separated into a single filament and the heat treatment with application of vapor is subsequently applied thereto, a special attention must be paid to prevent the vapor from condensing around the supply port.

Furthermore, according to the apparatus of the present invention, although it provides the protection measure for the filament not to entangle in the feeding rollers since it is constructively transported also by the gas stream, an auxiliary unit for filament suction as shown in FIG. 4 may be arranged therein as a further improvement in the filament feeding effects. Such a unit also has an effect to facilitate a process of passing the filament through its feeding inlet while in a rapid treating operation. In FIG. 4, reference numeral **1** designates a filament before being heat-treated, **17** is an auxiliary unit providing for filament suction, **3** is a primary hot gas supply port, **5** is a secondary gas supply port, and **6** is a heating cylinder.

The heat treatment according to the present invention may be directly connected with the stretching process in order, for example, to effect successively stretching and heat-treating, as shown in FIG. 9. In this case, the feeding rollers may also serve as stretching rollers.

In the apparatus of the present invention, a filament may be sometimes subject to heat treatment under the condition by which torque is produced in the filament. In some other cases, however, even slight false twist will bring an unfavorable result and, in these cases, the circulation of the primary gas stream should be inhibited.

In the case of lack of the secondary gas stream, defects will arise such as unfavorable quality or disorder in appearance of the heat-treated filament. Further, when a filament having the latent crimping ability is heat-treated without the secondary gas stream, uneven crimps are formed. On the contrary, in the present invention using the secondary gas stream, these defects are successfully eliminated.

Still, in the apparatus of the present invention, one or more filaments may be heat-treated separately or simultaneously. When a plurality of filaments are heat-treated at the same time, the sections of the primary gas stream inlet and of the heating cylinder may be favorably formed of rectangular shape.

Some examples of the heat-treatment by the use of the apparatus of the present invention are illustratively shown below.

EXAMPLE 1

Crystalline polypropylene was melt-spun and cooling air was applied from one side to obtain an undrawn filament having a markedly asymmetric inner structure in the lengthwise direction. The undrawn filament was stretched three folds on a hot pin at 60° C. to obtain a drawn filament of strong crimping property with 36 filaments and 158 deniers. The drawn filament was heat-treated using an apparatus as shown in FIG. 1. under the following conditions:

Feeding velocity: 400 m./min.
Take-up velocity: 200 m./min.
Primary hot gas stream: air
  Pneumatic pressure: 0.08 kg./cm.^{2} (gauge pressure)
  Flow amount: 200 ml./sec.
  Temperature: 140° C.
Supply port:
  Diameter of filament inlet: 2 mm.
Heating cylinder:
  Diameter: 25 mm.

Length: 400 mm.
Inner temperature: 140° C.
Secondary hot gas stream: air
Temperature: 140° C.
Flow amount: 300 ml./sec.

The multifilament thus obtained was of a crimp number of 31 and a crimp index of 35%.

The crimp number was expressed by the number of crimps per inch under a tension of 2 mg./d. The crimp index was calculated according to the following equation:

$$\frac{b-a}{b}\times 100(\%)$$

wherein b is the length of the specimen under a tension of 100 mg./d. and a is the length of the specimen under a tension of 2 mg./d.

EXAMPLE 2

A multifilament of polyethylene terephthalate with 24 filaments and 50 deniers was false-twisted and wound up. The multifilament was heat-treated in the relaxed state using an apparatus provided with the head portion as shown in FIG. 2 under the following conditions:

Feeding velocity: 600 m./min.
Take-up velocity: 420 m./min.
Primary hot gas stream: air
Pneumatic pressure: 0.05 kg./cm.^{2} (gauge pressure)
Flow amount: 150 ml./sec.
Temperature: 155° C.
Supply port:
Diameter of filament inlet: 1.5 mm.
Heating cylinder:
Diameter: 25 mm.
Length: 500 mm.
Inner temperature: 155° C.
Secondary hot gas stream: air
Temperature: 155° C.
Flow amount: 300 ml./sec.

As the result, a multifilament of a crimp index of 40% and of no residual torque was obtained.

EXAMPLE 3

A multifilament of polyethylene terephthalate 9-isophthalate 1 copolymer of a shrinkage rate of 12.5% when treated with boiling water for 30 minutes and of 24 filaments and 50 deniers was heat-treated in the relaxed state using an apparatus as shown in FIG. 5 under the following conditions:

Feeding velocity: 400 m./min.
Take-up velocity: 330 m./min.
Hot gas stream: air
Pneumatic pressure: 0.15 kg./cm.^{2} (gauge pressure)
Flow amount: 400 ml./sec.
Temperature: 175° C.
Supply port:
Diameter of filament inlet: 2.0 mm.
Heating cylinder:
Diameter: 25 mm.
Length: 500 mm.
Inner temperature: 175° C.
Recycled gas stream: air
Temperature: 175° C.
Flow amount: 800 ml./sec.

As the result, a multifilament of a shrinkage rate of 3.7% when treated with boiling water and of excellent dimensional stability was obtained.

EXAMPLE 4

Polyethylene terephthalate of 0.68 in intrinsic viscosity and polyethylene terephthalate 9-isophthalate 1 copolymer of 0.65 in intrinsic viscosity were subjected to conjugate melt spinning to obtain a side-by-side type bicomponent filament with 30 filaments and 585 deniers. The undrawn filament was continuously stretched and heat-treated in the relaxed state using an apparatus as shown in FIG. 9 under the following conditions:

Conditions for stretching:
Feeding velocity: 50 m./min.
Temperature of pin: 75° C.
Temperature of hot plate : 130° C.
Stretching rate: 4.5 folds
Conditions for heat-treatment:
Feeding velocity: 225 m./min.
Take-up velocity 150 m./min.
Hot gas stream: air
Pneumatic pressure: 0.4 kg/cm.^{2} (gauge pressure)
Flow amount: 500 ml./sec.
Temperature: 150° C.
Supply port:
Diameter of filament inlet: 2.0 mm.
Width of slit: **0.2 mm.**
(After application of the filament, the lower portion of the slit was closed with a thin plate of 0.2 mm. wide.)
Heating cylinder:
Diameter: 300 mm.
Length: 600 mm.
Width of slit: 0.2 mm.
Inner temperature: 150° C.

As the result, a bulky filament of a crimp index of 35% was obtained without entangling. The application of the filament to the apparatus was carried out with an excellent efficiency and a great facility.

What is claimed is:

1. An apparatus for the treatment of a filament in the relaxed state with a primary hot gas stream which comprises a heating cylinder, an inlet portion for the filament provided at one end of the cylinder, an outlet for the filament provided at the other end, and an outlet for a secondary gas stream provided near said inlet portion, the filament being joined by said primary hot gas stream at the inlet portion and then introduced through the inlet portion into the cylinder, wherein the heating cylinder is surrounded by a jacket having an upper port near a filament inlet in the inlet portion for the filament and a lower port at an appropriate position lower than the filament inlet, and the hot gas stream is introduced from an optical position lower than the filament inlet into the jacket and circulated through the upper port into the heating cylinder.

2. The apparatus according to claim **1**, wherein a narrow slit is provided between the jacket and the heating cylinder in the direction of movement of the filament over the whole length of the apparatus.

3. The apparatus according to claim **1**, wherein a narrow slit is provided between the jacket and the heating cylinder in the direction of movement of the filament over the whole length of the inlet portion for the filament and the heating cylinder.

4. The apparatus according to claim **1**, wherein the length of the heating cylinder is from 30 cm. to 2 m.

5. The apparatus according to claim **1**, wherein the cross section of the heating cylinder is from 4 to 200 times larger than that of the introduction portion of both filament and primary hot gas in size.

6. The apparatus according to claim **1**, wherein the flow amount of primary hot gas per each filament is from 10 to 4,000 ml./sec.

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