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MULTI-STAGE DRAWING OF NYLON FILAMENTS

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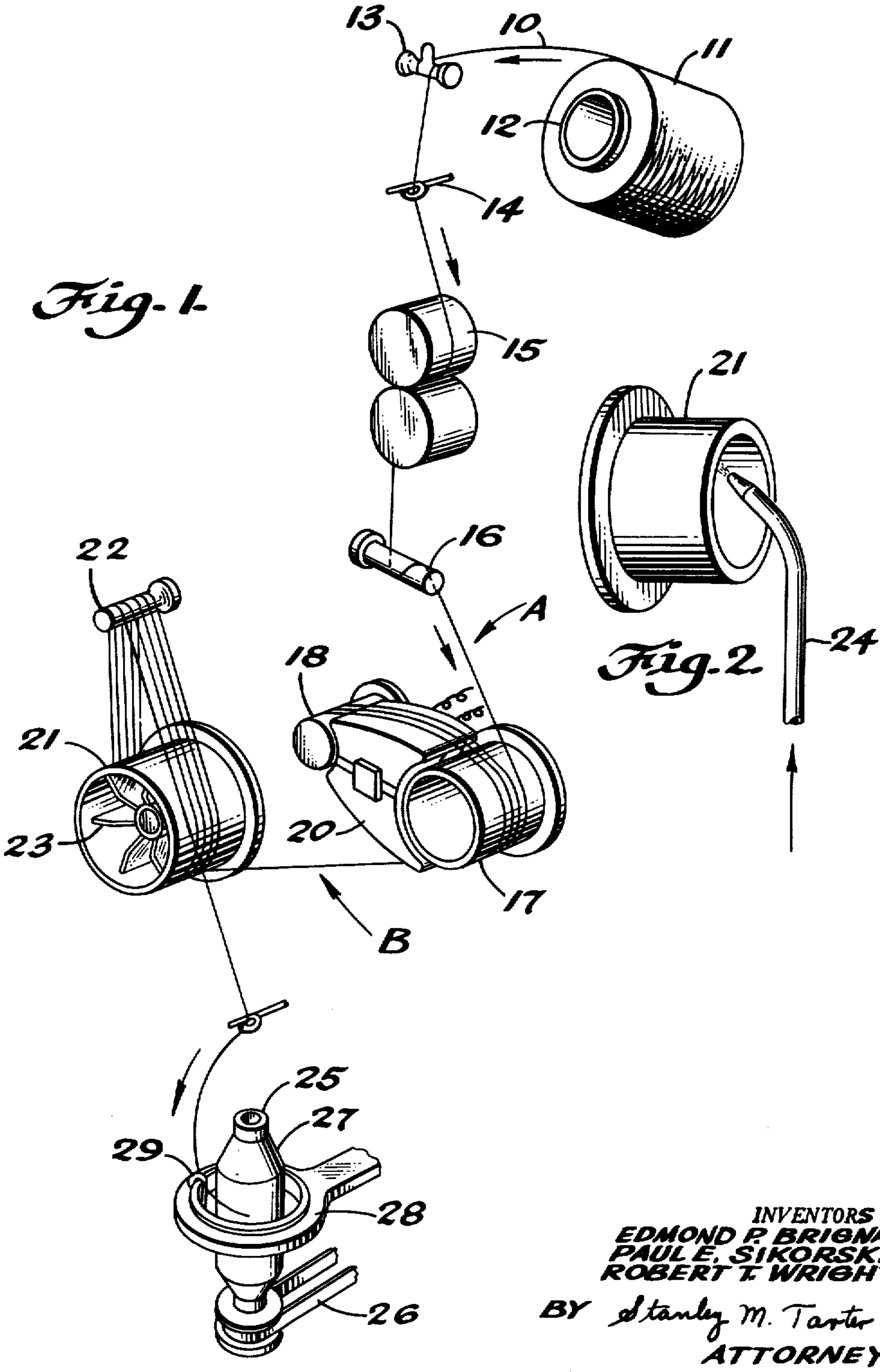

Fig. 1.

Fig. 2

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MULTI-STAGE DRAWING OF NYLON FILAMENTS

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This invention relates to drawing nylon filaments in multi-stages. More particularly, the invention relates to a method for the multi-stage attenuation of nylon filaments to improve the physical properties thereof.

Nylon filaments have made a substantial penetration into the tire cord market and other end uses, wherein high tenacity is a demanded property. One of the former drawbacks to the use of nylon cord-containing tires for passenger cars was the tendency of such tires to increase undesirably in size during normal use conditions. To minimize this drawback and to meet the increasing demands for higher tenacities, "hot-stretch" processes and apparatus have been developed and used during the past few years. Various arrangements have been proposed for thermally conditioning nylon filaments during the drawing thereof to impart higher tenacity thereto. Unfortunately, the hot-stretch procedures have given rise to concomitant problems. One of the problems is that the frequency of breakage of the individual filaments, as well as breakage of the whole threadline, notably increases where attempts are made to obtain higher strength levels by means of the known hot-stretch processes.

It is an object of the present invention to provide a method for multi-step attenuation of filaments to achieve improved tenacity without sacrifice of filament quality and toughness.

It is a further object of the present invention to provide an improved method of stretching nylon filaments in a two-stage operation involving consecutive heating and cooling under controlled conditions, whereby the tenacity thereof is increased without a marked reduction in filament quality.

Other objects may become apparent from the following detailed description of the invention.

In general, the objects are accomplished by stretching nylon filaments in two different stages under controlled conditions. Nylon filaments capable of being molecularly oriented, such as freshly spun filaments or "as spun" filaments, are fed longitudinally to a first stretch zone at a predetermined rate and are withdrawn therefrom at a predetermined increased rate so that the filaments are stretched to increase the molecular orientation thereof. The draw ratio employed in the first zone is determined by the overall draw ratio and the draw ratio employed in the second stretch zone. The overall draw ratio, i.e., the number obtained by dividing the speed of the yarn fed to the first zone into the speed of the yarn leaving the second zone, generally will not exceed 6.1 but should be sufficient for the filaments to have a tenacity of at least 8.5 grams per denier. Preferably, the overall draw ratio will be 5.0–6.0. In the first zone the filaments are snubbed so that there is a tendency of the point of necking down of the filaments to be localized, such as by the use of a snubbing pin, roll, or the like. When snubbed, the yarn temperature in the first zone should be about 20–85° C. The partially oriented filaments are heated immediately upon their exit from the said first zone to a temperature of about 160–190° C. The heat is applied while the filaments are maintained at substantially constant length. After attaining the desired temperature, the filaments are subjected to a draw ratio of about 1.2 to 1.9 in a second stretch zone simultaneously while the filaments are being cooled. As will be appreciated the product of the draw

ratio of the first zone and the draw ratio of the second zone will equal the overall draw ratio. The filaments should not be snubbed during this second drawing and are stretched to a highly oriented state. Then, the filaments are quickly quenched by suddenly cooling the drawn filaments to a temperature at least 60–90° C. below the elevated temperature obtained by the filaments between the first and second stretch zones. Thereafter, the filaments are taken up in an orderly manner by conventional means.

One form of apparatus for stretching the filaments in the multi-stage operation herein described includes suitable means for supplying molecularly orientable filaments from a source at a predetermined rate. A first yarn forwarding means is provided in the yarn path and is adapted to forward the yarn at a speed such that the yarn is attenuated a predetermined extent between the supplying means and the forwarding means. Disposed in the yarn path therebetween is a yarn snubber to apply a predetermined resistance to the forward movement of the yarn so that the point of stretching of the filaments is localized. A heating element is associated with the yarn forwarding means so that the yarn is heated to a predetermined elevated temperature. A second yarn forwarding means is provided in the yarn path and is adapted to be operated at a predetermined increased rate as compared with the rate of the first yarn forwarding means so that the yarn becomes fully stretched. The second forwarding means has a heat conducting surface for dissipating the heat from the yarn quickly. Means is provided so that the second forwarding means is cooled.

The amount that one draws the filaments in the first stretch zone is important, since the filaments before being subjected to the subsequent steps should exhibit some increased degree of molecular orientation as compared with the orientation of the filaments as spun. Increasing the molecular orientation of the filaments in the first zone, when carried to extremes, hinders the filaments from accepting the benefits in regard to tenacity and yarn quality bestowed by the subsequent steps of the method. If the orientation of the filaments is not sufficient, the same hindrance is present. As indicated above, the amount of draw in the first zone is ordinarily computed once the overall draw ratio and the draw ratio in the second stretch zone have been selected. It is important that the filaments during their travel through the first stretch zone be snubbed so that there is a tendency of the point of draw to be localized. The ambient temperature in the first zone can be that ordinarily employed in the conventional single stage cold-drawing of nylon filaments. At the point where the yarn is snubbed the temperature can be about 20–85° C., although the preferred temperature range is 35–80° C. Necking down of the filaments ordinarily occurs in the yarn path just beyond the point where the filaments are snubbed.

After being stretched in the first zone, the filaments are continuously heated to a temperature above the glass transition temperature but not higher than 30° C. below the melting temperature of the polymer. The preferred temperature is in the range of 160–190° C. The most satisfactory range is 180–185° C. One preferred embodiment of the invention comprises heating the partially oriented filaments with dry heat, such as by passing them over a heated surface in contacting engagement therewith. For example, this can be accomplished by passing the filaments across a heated surface and draw roll a plurality of times. The primary purpose of the draw roll is to transport the filaments across a heated surface and to maintain enough tension on the threadline to urge contact of the filaments with the heated surface. Multiple passes are desired to allow the heat to permeate the filaments fully. The filaments while heated are maintained at substantially constant length and under considerable tension. That is to say, the filaments are not stretched a large extent while they are heated. Preferably, the filaments should not be attenuated more than 8 percent during the heating stage. By being heated while restrained to substantially constant length, the filaments will be heat-set. However, the heating-setting action is only a partial one; and hence, the time during which the filaments are heated at substantially constant length is important. The time can be from about 0.05 to 0.80 second, preferably from 0.20 to 0.50 second.

After reaching the aforesaid temperature during the heating step, the filaments are stretched in a second stretch zone. The draw ratio employed in the second stretch zone is about 1.2–1.9, preferably 1.4–1.6. While being stretched, the yarn is cooled. This ordinarily can be accomplished by stretching the yarn in air at about room temperature or at some temperature notably below the temperature reached by the filaments when they were heated. An ambient temperature of 20–85° C. is quite satisfactory.

When stretching is completed, the filaments are quenched quickly. The post quenching is quite important to the practice of the invention. In a preferred embodiment, cooling is accomplished by passing the yarn over a heat conducting roll which functions as a heat sink. The temperature of the filaments should be reduced to a temperature at least 60–90° C. below the temperature attained by the filaments in the heating step. Where a cooling roll is employed, the yarn can be cooled quickly by suitable means to a temperature of about 10–110° C., preferably 30–80° C.

The yarn is thereafter taken up in an orderly manner.

The invention is further illustrated by reference to the accompanying drawing wherein:

FIGURE 1 is a schematic view in perspective with principal parts in location illustrating one arrangement of apparatus suitable for stretching nylon filaments in the two stage operation of the invention; and

FIGURE 2 is a perspective view on a larger scale illustrating a heat dissipating roll different from that shown in FIGURE 1.

Yarn **10** to be stretched and composed of a bundle of smooth substantially parallel filaments that have not been fully oriented is supplied from a yarn source. The yarn source can be, for example, yarn package **11** previously doffed from a conventional spinning machine. However, the apparatus can readily be adapted for processing continuous filament yarn which is supplied directly from the spinning machine without an intermediate take up. Yarn **10** is passed over and around one end of bobbin **12** or other yarnholder. The yarn **10** is threaded conventionally around snubbing bar **13** which functions as a simple, uncomplex tensioning device to assist in maintaining an orderly and uniform supply of yarn. From the tensioning device the yarn **10** is passed through a yarn guide **14**, if needed, and then to a rotatably arranged thread advancing means **15** that is adapted to supply yarn to the first stretch zone A at a first delivery speed. Means **15** can comprise a pair of feed rolls, at least one of which is positively driven. The rolls engage each other to nip the yarn sufficiently. From thread advancing means **15** the yarn **10** is led downwardly and around a snubbing pin **16** or like snubbing means. The pin is mounted to be non-rotative and has a smooth yarn contact surface made of resistant to wear material.

After being passed around pin **16** a desired number of times, the yarn **10** is directed around rotatably mounted feed roll **17** and its associated separator roll **18** which is freely rotatably mounted. Roll **17** is positively driven at a peripheral speed such that the yarn is given a predetermined stretch between the roll **17** and means **15** which defines the stretch zone A. Mounted between the roll **17** and roll **18** is a heater block **20** providing a source of dry heat for raising the temperature of the yarn while it slides across the surface of the block. The heating of the block can be achieved in a suitable manner, e.g., by internal electric resistant heating.

After attaining the required elevated temperature, the yarn is led around the periphery of a cooling roll **21** and its associated separator roll **22**. The peripheral speed of roll **21** is faster than the peripheral speed of roll **17** so that the yarn is stretched a predetermined amount therebetween in the stretch zone **B**.

In the embodiment of FIGURE 1 roll **21** is provided with internal vanes **23**. During rotation of this roll, the vanes will propel air from the atmosphere through the inside of the roll. As indicated above, the roll is made of a heat conducting substance. Hence, heat conducted from the yarn will be carried from the roll by the movement of the air therethrough.

From a study of FIGURE 2, it will be apparent that roll **21** can be cooled in a different manner. In the embodiment of this figure, nozzle **24** is connected to a source of cool compressed air or other fluid coolant. The nozzle extends interiorly of roll **21** and is curved at its end to direct the coolant inside the roll.

The yarn after being cooled quickly is taken up in a conventional manner by a suitable form of a package building apparatus such as a ring twisting assembly which comprises a bobbin **25** adapted to be rotated by driven belt **26** to form a package **27**. The assembly further includes a vertically reciprocated ring **28** carrying a traveller **29** adapted to revolve freely around the bobbin **25** as the yarn is twisted a desired amount and wound thereon.

The following examples will serve to illustrate the invention, although they are not intended to be limitative. The yarn employed in each case was melt spun from nylon-66 (polyhexamethyleneadipamide). However, yarn prepared from other types of nylon polymer can be processed in accordance with the present invention. Other types of nylons include nylon 4, nylon 6, nylon 610, nylon 11, and their fiber-forming copolymers, e.g., 6/66, 6/610/66, 66/610, etc. Nylon, as is well known, has recurring intralinear carbonamide groups as an integral part of the main molecular chain.

EXAMPLE I

A 140 filament nylon-66 yarn with a spun denier of 4250 was pulled from a "spin cake bobbin" by means of a drawtwister feed and top-cot roll assembly and fed to and around a first stage drawing pin. The pin temperature was 38° C., and the draw ratio was 3.82 in this first stage. The threadline was heated then by being passed over a heater block at 180° C. disposed between a draw roll and an accessory separator roll. Multiple threadline wraps were made around the roll-heater block assembly to raise the yarn temperature to about 170° C. while the yarn was maintained at substantially constant length. The yarn was then drawn in a second stage at a draw ratio of 1.5 which was accomplished by running a larger draw roll with a peripheral yarn speed 1.5 times the peripheral speed of the smaller draw roll. No external heat was applied during this second stage drawing. The yarn was then cooled by running multiple wraps around the larger draw roll and separator roll assembly. The larger draw roll was heat conductive and was interiorly vaned so that heat was dissipated therefrom. The temperature of the vaned roll was approximately 50° C. Filament breakage and wrap formation were almost non-existent under the above conditions; and the resulting drawn yarn had a tenacity of 10.2 grams per denier and an elongation of 12.8%. The overall drawing speed was 190 yards per minute, and the overall draw ratio was 5.73.

EXAMPLE II

By using the apparatus illustrated in FIGURE 1, a 140 filament nylon-66 yarn with a spun denier of 4710 was stretched in two stages with intermediate heating. After the second stage, the yarn was quickly cooled. In this instance the snubbing pin temperature was 46° C., and the draw ratio was 3.94 in the first stage. The heater block had a temperature of 182° C. The second stage draw ratio was 1.5. The temperature of the vaned draw roll was 55° C. The take-up speed was 466 yards per minute.

Filament breakage and threadline breakage were almost non-existent under these process conditions. The yarn had a tenacity of 8.6 grams per denier and an elongation of 12.0%.

EXAMPLE III

In a known manner wherein nylon filaments are stretched in two stages, freshly formed multifilament nylon-66 yarn was advanced through the first stage. The pin temperature in this stage was 35° C. Then, the yarn was led through the second stage in which the yarn passed around a second snubbing pin and then over the heating surface of a hot block operated at a temperature of 180° C. The overall draw ratio was 5.7, and the draw ratio in the second stage was 1.5. The final denier of the yarn was 776; the tenacity thereof was 9.9; and the elongation thereof was 12.1. While the tenacity and elongation were quite satisfactory, the yarn had so many filament breaks that many packages of the yarn had to be rejected as being substandard.

On the other hand when the same yarn was processed under like conditions employing the apparatus in FIGURE 1, there were 27 percent less packages rejected. The yarn was not snubbed in the second zone but was heated between the first and second stages as the yarn was kept at constant length. Also, the yarn was quickly quenched by being passed over a cool heat-conducting roll immediately upon its exit from the second stage. The tenacity of the yarn was 9.8, and the elongation thereof was 13.5. When the yarn was processed in accordance with this invention, breaking of the whole threadline during the operation as compared with the breaking frequency when the yarn was processed in the known manner occurred only one-half as often. In addition, the number of wraps of broken filaments picked up by the thread advancing rolls was notably less when the yarn was processed by the method of the present invention.

EXAMPLE IV

As a control, freshly formed multifilament nylon-66 yarn was drawn in the known manner described in Example II. The yarn performance was compared with the performance obtained by processing the yarn in accordance with the present invention. Various overall draw ratios and block temperatures were employed as indicated in the table below. The first stage draw ratio was 1.5 in each instance.

Table

CONTROL

Draw Ratio	Block Temp., ° C.	Tenacity	Drawn Denier	Quality
5.65	170	9.5	801	Rejected.
5.65	180	9.6	802	Do.
5.73	180	9.4	796	Do.
5.73	190	9.5	793	Do.
5.82	180	9.8	782	Do.

PRESENT PROCESS

Draw Ratio	Block Temp., ° C.	Tenacity	Drawn Denier	Quality
5.65	170	9.2	796	Standard.
5.65	180	9.1	796	Do.
5.73	180	9.4	789	Do.
5.73	190	9.5	780	Do.
5.82	180	9.7	772	Do.

From these data, it is seen that the quality of the yarn processed in accordance with the present invention is much better. The number of threadline breaks and the number of breaking of individual filaments were observed to be less.

Numerous advantages are associated with the present process. One is able to produce a high tenacity nylon yarn of high quality. The operability of the process is excellent; and one is able to employ high overall draw ratios with a small number of thread breaks per pound of yarn drawn. Conventional drawing equipment can be employed with only minor modifications thereof. Other advantages may be noted.

Any departure from the description herein that conforms to the spirit of the invention is intended to be included within the scope of the following claims.

What is claimed is:

1. A process for treating nylon filaments comprising the steps of longitudinally feeding nylon filaments capable of being molecularly oriented to a first stretch zone at a predetermined rate, withdrawing the said filaments from said first zone at a predetermined increased rate, whereby the filaments are attenuated therein, snubbing the movement of said filaments through the said first zone so that there is a tendency of the point of the necking down of the filaments to be localized, the temperature of the filaments when snubbed being about 20–85° C., heating the filaments upon their exit from the said first zone to a temperature about 160–190° C., the heat being applied while the filaments are maintained at substantially constant length, and for a period of time of about 0.05 to 0.80 second, immediately thereafter attenuating the heated filaments an additional amount in a second stretch zone while cooling the filaments and without snubbing thereof in the said second zone, then quickly quenching the filaments at a temperature at least 60–90° C. below the elevated temperature obtained by the filaments when heated at substantially constant length, and taking the filaments up in an orderly manner, the overall draw ratio employed being not more than 6.1 but being sufficient for the filaments to have a high tenacity and the draw ratio employed in the second stretch zone being about 1.2–1.9.

2. The process of claim 1 wherein the nylon is nylon-66.

3. A process for treating nylon filaments comprising the steps of continuously longitudinally feeding freshly spun nylon filaments capable of being molecularly oriented to a first stretch zone at a predetermined rate, continuously withdrawing the said filaments from said first zone at a predetermined increased rate, whereby the filaments are stretched therein to increase the orientation thereof, continuously snubbing the movement of said filaments through the said first stretch zone so that there is a tendency of the point of the necking down of the filaments to be localized, the temperature of the filaments when snubbed being 20–85° C., continuously heating the filaments upon their exit from the said first stretch zone to a temperature about 160–190° C., the heat being applied while the filaments are maintained at substantially constant length and for a period of time of about 0.05 to 0.80 second, immediately thereafter continuously attenuating the heated filaments an additional amount in a second stretch zone while at the same time cooling the filaments and without snubbing thereof in the said second zone, then continuously quickly quenching the filaments at a temperature at least 60–90° C. below the elevated temperature obtained by the filaments when heated at substantially constant length, taking the filaments up in an orderly manner, the overall draw ratio employed being 5.0–6.0 and the draw ratio employed in the second stretch zone being about 1.2–1.9.

4. The process of claim 3 in which the nylon is nylon-66.

5. A process for treating nylon filaments comprising the steps of continuously feeding freshly spun nylon filaments capable of being molecularly oriented to a first stretch zone at a predetermined rate, continuously with-

drawing the said filaments from said first stretch zone at a predetermined increased rate, whereby the filaments are stretched therein to increase the molecular orientation thereof, continuously snubbing the movement of said filaments through the said first stretch zone so that there is a tendency of the point of the necking down of the filaments to be localized, the temperature of the filaments when snubbed being 35–80° C., continuously heating the filaments upon their exit from the said first stretch zone with a dry heat source by passing the filaments over the heat source in contacting engagement therewith whereby the temperature of the filaments is raised to about 180–185° C., the heat being applied while the filaments are maintained at substantially constant length and for a period of time of 0.20 to 0.50 second, immediately thereafter attenuating the heated filaments an additional amount in a second stretch zone while at the same time cooling the filaments and without snubbing thereof in the second stretch zone, the ambient temperature employed in the second stretch zone being 20–85° C., then continuously quickly quenching the filaments at a temperature of 30–80° C. by contacting same with a cool heat conductive surface, and taking the filaments up in an orderly manner, the overall draw ratio employed being 5.0–6.0 and the draw ratio employed in the second stretch zone being 1.4–1.6.

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