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STRETCHING NYLON FILAMENTS IN A GAS VORTEX

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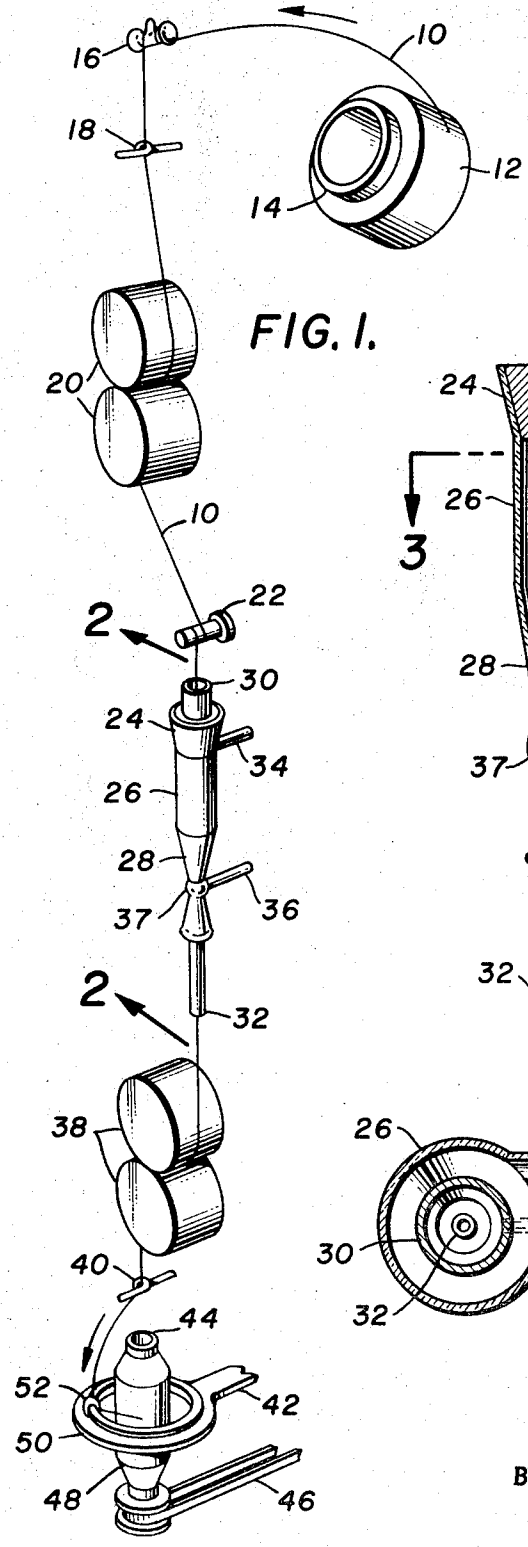


FIG. 1.

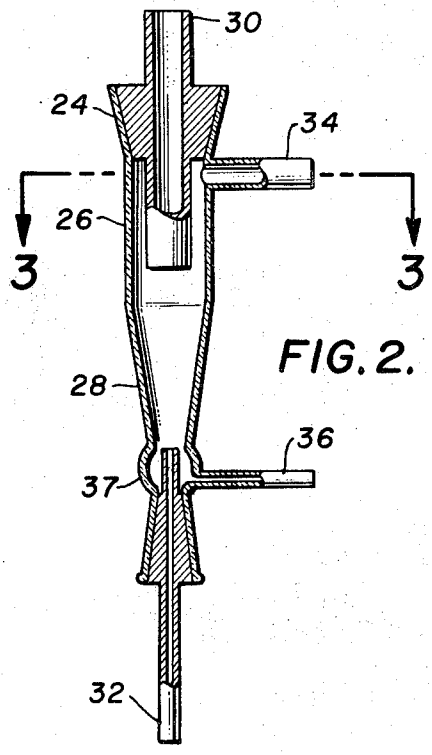


FIG. 2.

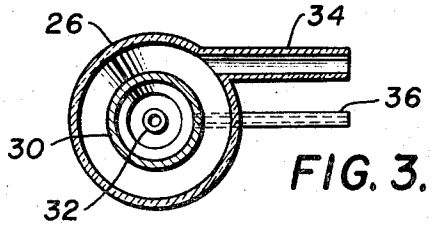


FIG. 3.

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STRETCHING NYLON FILAMENTS IN A GAS VORTEX

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ABSTRACT OF THE DISCLOSURE

Thermoplastic filaments and especially nylon filaments are highly stretched by a process of rapidly heating the filaments by subjecting the filaments to a high temperature gas vortex and simultaneously stretching the filaments whereby high tenacity filaments are obtained. The draw ratio can be 5.5:1 and above, and the gas temperature can be from 250° C. to 325° C.

This invention relates to the drawing of filamentary strands. More particularly, the invention is directed to an improved process and apparatus for drawing yarns, particularly of tire cord count, at high draw ratios.

Normally, in the production of continuous filament yarns, the as-spun filaments are drawn or attenuated. The purpose of this drawing is to impart a molecular orientation along the filament axis to thereby increase the tensile strength or tenacity of the filament. The greater the attenuation, or the higher the draw ratio obtained during this draw process, the greater the tensile strength attained in the filaments. Ofttimes the drawing is conducted at room temperature, commonly termed cold-drawing. In the case of tire cords, however, in which relatively high tensile strengths are necessary and which, therefore, require greater draw ratios, the filaments must be drawn at elevated temperatures in order to attain the necessary degree of attenuation without undue filament breakage.

One method by which tire cords are attenuated and oriented by this so-called hot drawing procedure, is by employing a "hot slot" arrangement. In this method, the yarn is advanced by a set of godet rolls to and around a draw pin, where the yarn is drawn and then forwarded by the use of a second set of godet rolls, commonly referred to as draw rolls. The "hot slot" is employed between the draw pin and the draw rolls to heat the yarn to permit the attainment of high draw ratios and consequent high tensile strengths. This hot slot, as commonly employed, usually consists of a milled slot formed in a series of aluminum blocks held together in laminated fashion to form a composite block which averages 4 feet in length, as measured along the path of the yarn being processed. Though dimensions are found to vary somewhat, a typical size would be one-half inch deep by three-sixteenths inch in width. In other words, the slot is of such dimensions that it will allow passage of the yarn through the heated blocks with a minimum clearance to promote rapid heat transfer, yet providing sufficient clearance to keep the yarn from coming in contact with the walls of the slot. Each longitudinal zone of a foot or so in length of the composite block is heated by electrical resistance heaters which may be thermistor controlled so that the temperature block can be maintained at any desired temperature between 200 and 300° C. The yarn passing through the slot is heated mainly by convection from the hot air surrounding the yarn bundle, although a small amount of heat is transferred to the yarn by radiation from the surface of the heated metal block.

In this hot slot method of drawing tire cords, there are

several disadvantages and undesirable features. One of the most undesirable features is that the rate of heat transfer from the hot slot to the yarn is very low. This is due, at least in part, to the fact that the yarn travels through what is essentially stagnant hot air within the slot. Because of this, a bulky long piece of equipment must be employed, often greater than 4 feet in length, in order to allow for sufficient heat transfer to the yarn to obtain the temperatures necessary to conduct high draw ratio operations. Additionally, because of the open configuration of the hot slot, it is not economically feasible to employ a gas other than air as a heat transfer medium even though other gases have a higher coefficient of heat transfer. It would be desirable, in the drawing operation, to employ a non-oxidizing medium, such as nitrogen, in order to prevent degradation and yellowing of the yarns during exposure to the high temperatures incident to conventional hot slot processing. Another disadvantage of the hot slot is that the temperature of the hot stagnant air within the slot cannot be ascertained with any great accuracy and, because of the design of the equipment, the variation in temperature along the length of the slot may be subject to considerable variation, rendering it very difficult to determine the optimum operating conditions for a given production run.

With the above in mind, it therefore becomes an object of the present invention to provide a process and apparatus for obtaining yarn of ultra-high tensile strength.

Another object of the present invention is to provide an improved process and apparatus for drawing tire cord to very high draw ratios.

A further object of the subject invention is to provide a process and apparatus for increasing the rate of heat transfer from a hot gas to a yarn moving at high speeds.

Still another object of this invention is to provide an improved process and apparatus whereby nylon yarns may be drawn at precisely controllable temperature levels to thereby promote product uniformity.

These and other objects and advantages of the present invention will become apparent from the following detailed description thereof, when considered in connection with the accompanying drawings, wherein like reference numerals designate like or similar parts and in which:

FIG. 1 is a diagrammatic perspective view illustrating one embodiment of an apparatus designed to carry out the process of this invention;

FIG. 2 is an elevational view, partly in section, illustrating one embodiment of the heat transfer apparatus used in carrying out the process of this invention, and

FIG. 3 is a cross-sectional view of the apparatus shown in FIG. 2 taken along line 3—3 of FIG. 2 and showing details of construction of the heat transfer device.

In general, according to the invention, there is provided an improved process and apparatus for drawing continuous filament yarns at high speeds and high draw ratios, which apparatus is designed for efficient and economical operation. This efficiency and economy is made possible by the use of a novel heat transfer device wherein the running continuous filament yarn may be heated to very high temperatures over a small linear distance. The stated objectives are attained by feeding yarn from a suitable source of supply through a feed roll assembly after having been passed through or around a suitable tensioning device, if desired. At least one roll of the feed roll assembly is positively driven. As is well known, the purpose of the feed roll assembly is to provide a supply of yarn at a predetermined and precisely controllable rate with the provision that the yarn will undergo slippage through the feeding assembly due to the attenuating tensions subsequently to be applied. Upon leaving this first roll assembly, the yarn passes over and

around a stretch or draw pin and the attenuation of the filaments tends to be localized at this draw pin. In the portion of the yarn path downstream of the first roll assembly and drawing pin, there is disposed a heat transfer device, the details of which constitute an important aspect of this invention. While passing through such a heat transfer device, the traveling yarn is heated to very high temperatures over a short linear distance. This rapid heating to high temperatures is accomplished by the use of hot gases entering the heat transfer device tangential to the path of the yarn, to thereby flow around and along with the yarn in a centrifugal or cyclonic fashion through the apparatus. Once the yarn leaves the heat transfer device, it passes through and around a draw roll assembly of a construction similar to that of the previously mentioned feed roll assembly. At least one of the rolls of this draw roll assembly is positively driven in order that the yarn may be stretched or attenuated between the feed and draw assemblies at a predetermined draw ratio to thereby impart the desired amount of draw or attenuation to the yarn between the two roll assemblies. After being drawn, the yarn is forwarded through a guide and is taken up in package form by any suitable means, such as a traversing ring traveler arrangement.

Referring now to FIG. 1 of the drawings, wherein the apparatus comprising one aspect of this invention is shown in a typical arrangement, a thermoplastic, draw-orientable yarn, indicated generally by reference numeral **10**, in the form of a tow or bundle of substantially parallel, undrawn filaments, is supplied from a yarn source. The yarn source can be, for example, in the form of a yarn package **12** previously doffed from a conventional spinning machine. While the invention will be described primarily in connection with an apparatus which employs a yarn package so doffed, it is to be borne in mind that this is merely for the purpose of convenient illustration and is in no sense to be taken as a limitation since the apparatus, according to the present invention, may as well be employed in the processing of continuous yarns which have not been previously doffed from a filament spinning machine.

As shown, yarn **10** is passed over and around one end of bobbin **14**, or other suitable yarn holder, such as a pirn or cone. The yarn **10** is threaded around any suitable tensioning device **16** which functions to maintain an orderly and uniform supply of yarn. From the tensioning device **16**, the yarn **10** is, if convenient, passed through a yarn guide **18**, thence to a rotatably arranged thread advancing means in the form of a pair of contiguous feed rolls **20** to thereby withdraw the yarn from bobbin **14** and supply same at a controlled rate. The rolls are mounted on parallel axes and engage each other in operation to effectively nip the yarn passing therethrough so that slippage or free-flight of the yarn between the rolls is prevented.

From thread advancing means **20**, the yarn **10** is passed about draw pin **22** where the attenuation is largely localized. The pin is mounted axially askew with respect to the parallel axes of the feed rolls and have a smooth, wear resistant yarn contact surface. After being passed about pin **22** a desired number of turns, the yarn is passed through heat transfer device **24**, which is seen to consist of upper and lower communicating portions or chambers, **26** and **28**, respectively, as best viewed in FIG. 2. This heat transfer device has a yarn inlet opening **30** and a yarn outlet opening **32** and is so constructed that its lower portion **28** takes the form of an inverted, truncated cone. The hot gases employed to heat the yarn enter the heat transfer device through gas inlet **34**; a small portion of these gases leave the apparatus through gas outlet **36**. A major portion of the hot gases will normally escape through yarn inlet **30** located at the upstream end of the heat transfer device and thus preheat the yarn to some extent before it enters the apparatus.

After passing through the heat transfer device **24**, the yarn **10**, emerging through lower yarn outlet **32**, is passed about a pair of rotatably arranged draw rolls **38** which are arranged to be operated at a predetermined increase in speed relative to the feed roll arrangement **20** to thereby attain the desired draw ratio. After leaving the draw rolls **38**, the yarn is fed vertically downward to be taken up, usually through a pigtail-type yarn guide **40**, in an orderly manner by a suitable form of package building apparatus. As shown in FIG. 1, the yarn **10** is taken up by a ring-traveler assembly, generally denoted by reference numeral **42**, which is seen to comprise a bobbin **44** adapted to be rotated by a driven belt **46** to collect a package of yarn **48**. The assembly further comprises a vertically reciprocable traveler ring **50** carrying a ring-traveler **52** adapted to revolve freely about bobbin **44** as the yarn is twisted a desired amount and wound about the bobbin.

Reference is now made to FIG. 2, wherein the heat transfer device **24** comprising one aspect of this invention is shown on a large, partially sectionalized scale for greater clarity. This heat transfer apparatus consists of an upper chamber **26** and a lower chamber **28** communicating therewith. A yarn inlet opening **30** is formed in the upper end of upper chamber **26** and an outlet opening **32** is formed at the lower end of lower chamber **28**. Additionally, a hot gas inlet **34** and gas outlet **36** are provided by which there is circulated a suitable heating medium through the heat transfer tube **24**. The upper chamber **26** generally takes the form of a hollow cylinder, while that of the lower portion **28** is of the general form of an inverted truncated cone. The purpose of the conical lower portion **28** is to aid in creating a centrifugal vortex or cyclonic-like flow to the hot gases employed as the heat transfer medium. Such a shape additionally aids in directing the hot gas flow through the body of the heat transfer device and out through gas outlet **36**. Yarn inlet **30** at the upstream end of the apparatus can assume a variety of shapes and dimensions, preferably being somewhat larger than the yarn bundle to be processed to thereby provide an additional exit for the hot gases in addition to the gas exit **36**, whereby the filaments entering the apparatus will be preheated in their travel from the snubbing or draw pin **22** to the heat transfer device. Yarn outlet **32** leading from the apparatus should be sufficiently small in diameter to avoid excessive loss of hot gases from the device, but sufficiently large enough to freely permit passage of the yarn bundle. Hot gas inlet **34** should be near the top of the upper chamber **26** of the heat transfer device and should be sufficiently large in size to permit hot gas at temperatures in the range of 250–325° C. to pass therethrough at rates of 50–100 feet per second (f.p.s.). Gas outlet or eliminator **36** should be located near the base of the lower conical section of the apparatus. When the apparatus is in operation, gas inlet **34** may be connected to any suitable source of hot gas supply, not shown. Also, both the hot gas inlet and the gas outlet may be connected to a closed system which may provide for the supply, recycling and reheating of a hot gas. If so desired, a gas eliminator or outlet **36** may, of course, be vented to the atmosphere. Additionally, when a non-condensible gas or vapor is used in the treatment of the yarn, outlet **36** need not be employed and may even be blocked off. However, if a condensible vapor, such as steam, is used, this outlet **36** can be employed to effect removal of the condensed medium.

Most relatively inert gases which can be heated to high temperatures without decomposing are suitable for use in the process of this invention, some examples being air, nitrogen, helium, steam, and even hydrogen if proper safety precautions are taken. The heat transfer device is additionally provided with a small, spherical reservoir or trap **37** which has been found useful when vaporous heating mediums, such as steam, are employed. By applying a small vacuum to outlet **36**, which is arranged to communicate with the lower regions of the reservoir, condensate

accumulating therein is easily removed, along with minor uncondensed portions of the heating medium.

Reference is now made to FIG. 3 as showing a cross-section of the heat transfer device taken along line 3—3 of FIG. 2. As seen, the heat transfer apparatus is essentially circular in cross-section, having two concentric circular openings in the form of an inlet opening **30** and an outlet opening **32**. Hot gas inlet **34** is mounted to be off-center with respect to the vertical axis of the heat transfer device and can be seen as nearly tangential to the inside circumference of chamber **26**. The purpose of offsetting the hot gas inlet is to create a vortex flow of hot gases around the yarn passing therethrough. This form of gas flow, which combines transverse, rotary and longitudinal components, greatly increases the rate of heat transfer to the yarn. Because of this greatly increased heat transfer, yarn may be processed at increased rates with greater product uniformity.

In carrying out the typical examples which follow, the heat transfer device was constructed of glass. Its construction is, however, not limited to glass, but may be made of many other suitable materials, such as the metals.

As before related, it has been discovered that filamentary yarns of a thermoplastic, fiber-forming polymer which have not been stretch-oriented can be treated according to this invention to impart higher draw ratios to thereby obtain increased tensile strengths. The yarn is continuously passed through a stretching zone wherein the filaments are rapidly heated to an elevated temperature by the use of hot gases circulating within the heat transfer device in a centrifugal or cyclonic fashion, whereby heat transfer to the filaments is greatly increased to thereby permit higher draw ratios, resulting in higher tensile strengths. The process of the invention, because of the greatly increased rate of heat transfer to the yarn, also provides a much shorter processing distance for hot drawing operations.

The method of the present invention is applicable to a wide variety of continuous filament yarns, the only requirement being that the yarn is made from a thermoplastic, fiber-forming resin which can be extended by drawing to show an increased molecular orientation along the filament axis. The yarns may be formed by known techniques from these resins, including melt extrusion and wet spinning and dry spinning processes. As examples of fiber-forming synthetic polymers formed from thermoplastic fiber-forming resins which may benefit from the present invention, there may be mentioned polyethylene, polypropylene, polyurethanes, polycarbonates, etc. The process of this invention is applicable particularly to the treatment of nylon yarns, including nylon 66, nylon 4, nylon 6, nylon 610, nylon 1, and fiber-forming copolymers thereof.

This invention may be further illustrated by reference to the following examples, although it will be understood that these examples are included for purposes of illustration only and are not intended to limit the scope of the invention.

EXAMPLES I–V

For the purpose of drawing yarns according to the process and by means of the apparatus of this invention, a heat transfer device similar to that shown in FIG. 2 was employed. The yarn treating zone defined by the heat transfer device was approximately 4 inches in length, 1 inch in diameter at its widest point and approximately 3/16 inch in diameter at its narrowest section, i.e., at a point immediately upstream of outlet tube **36**. The yarn inlet opening **30** was approximately ½ inch in diameter and extended down into the yarn treating section approximately 1½ inches, while the hot gas inlet was approximately ¼ inch in diameter. The yarn exit and gas outlet were both approximately 2 mm. in diameter. In the above description all diameters are to be taken as inside diameters.

The filaments to be processed were prepared from the melt spinning of polyhexamethylene adipamide. The yarn obtained was composed of 140 undrawn filaments, each having a denier of approximately six. The yarn was fed through the system depicted in FIG. 1 of the drawing and into the heat transfer device **24** at an input speed of 31.4 feet per minute (f.p.m.). Nitrogen gas was used in these examples as the heat transfer medium and was fed through the hot gas inlet at a rate of 1 cubic foot per minute (measured at room temperature) and exhausted through the gas eliminator and outlet tube to the atmosphere. Yarns exhibiting the following tabulated properties of draw ratio, tenacity and elongation were obtained when employing nitrogen gas at the temperatures indicated:

Example	Temperature of N_2 gas, ° C.	Draw ratio	Tenacity, g.p.d.	Elongation, percent
I	286	5.50:1	10.53	15.5
II	286	5.60:1	10.73	15.9
III	286	5.70:1	11.06	14.5
IV	308	5.80:1	10.91	14.3
V	308	5.90:1	10.76	13.6

EXAMPLE VI

In this example, nylon yarn identical to that used in the first five examples was drawn by use of the previously described "hot slot" in lieu of using the heat transfer device of this invention. The "hot slot" was approximately 4 feet in length and the surface temperature of the aluminum block was maintained at 260° C. The maximum draw ratio obtainable using this device was 5.5 which gave a yarn tenacity of approximately 10.5 grams perdenier (g.p.d.), which is seen to be lower than that of either Examples I–V.

EXAMPLE VII

In this example, nylon yarn identical to that used in the previous examples was drawn on a drawtwister under optimum conditions in lieu of using the heat transfer device of this invention. Employing the best possible settings in the two-stage position of the drawtwister, the yarn could be drawn to a maximum draw ratio of 5.56. This draw ratio produced yarn having a tenacity of approximately 10.6 g.p.d., again resulting in a lower tenacity than that obtainable by the centrifugal heat transfer device of this invention.

In accordance with another embodiment of the present invention, the conical section **28** of heat transfer device **24**, as shown in FIG. 2, may be filled, or partially so, with small glass beads ranging in size from 3 to 6 mm. The addition of such beads was found to increase the rate of heat transfer within the device to the traveling yarn. When using this modified system, the yarn contacted the hot glass beads to produce a rolling action to thereby promote better heat transfer contact with the threadline. Because of the increased heat transfer from the hot glass beads to the running bundle of filaments, maximum draw ratios and maximum tensile strength could be obtained using lower operating temperatures for the hot gases circulating through the heat transfer device.

From the foregoing, it can be seen that the practice of this invention results in the production of highly oriented yarns possessing tensile strength of an order heretofore not to be feasibly obtained. The apparatus and process of the invention provide for the drawing of yarns in much shorter processing distances and at high rates of speed; the 4 inch length of the centrifugal heat transfer device of this invention is found to produce results superior to those obtainable by the use of a conventional 4 foot "hot slot." In addition, by using the apparatus of this invention, one can determine the precise temperature of the air or gas around the yarn to thereby promote better process control.

Obviously, numerous modifications and variations of the present invention will readily occur in the light of the

above teaching. It is, therefore, to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

What is claimed is:

1. A process for drawing polyhexamethylene adipamide filaments comprising the steps of drawing said filaments at a gratio greater than about 5.5:1, simultaneously subjecting said filaments to the influence of a high temperature gas vortex maintained at a temperature within the range of from about 250° to 325° C. to thereby effect high rates of heat transfer, whereby high tenacity filaments are obtained.

2. The process of claim 1 wherein said gas is nitrogen.

3. The process of claim 1 wherein the velocity of said gas is maintained in excess of about 75 feet per second.

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