June 4, 1963 C. E. DUSENBURY 3,091,805

APPARATUS AND PROCESS FOR DRAWING YARN

Filed Nov. 2, 1960

FIG. 1

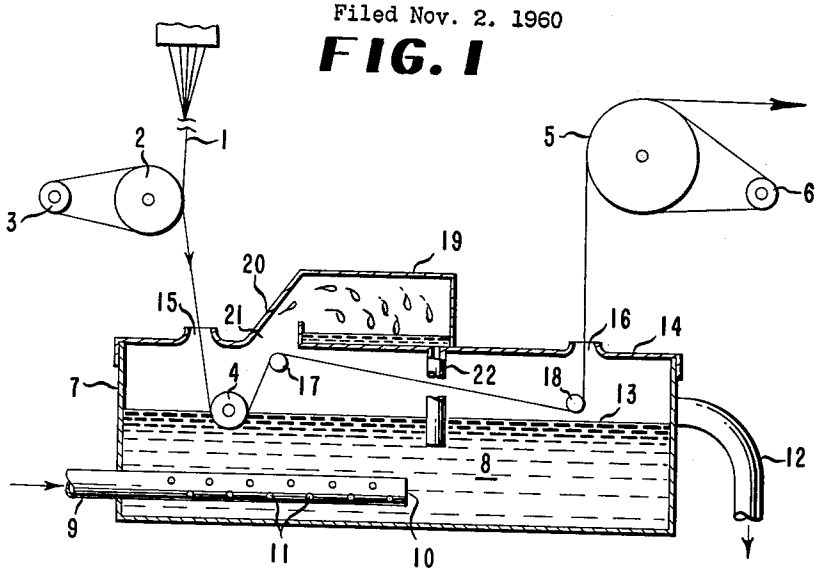


FIG. 2

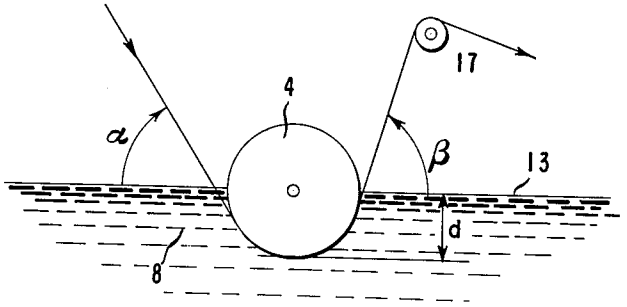
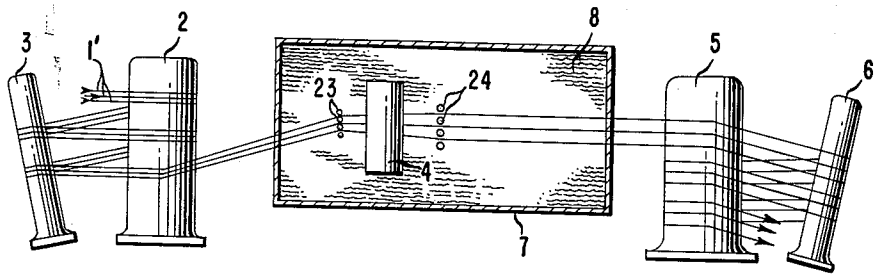


FIG. 3



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APPARATUS AND PROCESS FOR DRAWING YARN

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6 Claims. (Cl. 18—8)

This invention relates to a process and apparatus for orienting synthetic continuous filament yarns, especially at high speeds. The invention is particularly concerned with the high-speed orientation of a plurality of continuous filament yarns composed of a synthetic linear condensation polyester in a highly uniform manner to yield a product having improved yarn properties.

It is well known that synthetic yarns, and especially the melt-spun yarns such as those produced from the synthetic linear condensation polymers in the conventional range of spinning speeds, have relatively low tenacities as spun. However, when such yarns are stretched or drawn, they undergo orientation and become highly tenacious. Various types of apparatus have been developed in the past for the purpose of carrying out the step of orienting the synthetic yarns. However, since the desired degree of uniformity of the yarn product has been difficult to achieve hitherto, there has been a desire for new apparatus capable of orienting synthetic yarns in a highly uniform manner. Attempts have also been made to increase the speed of the orientation step to improve productivity; however, at speeds on the order of 2,000 yards per minute and above it has been found difficult to maintain the continuity of drawing and to maintain the desired yarn physical properties. Accordingly, a process and apparatus have been desired with which high drawing speeds could be achieved while maintaining or improving yarn physical properties and yarn uniformity.

Among the synthetic yarns which have been of commercial importance in recent years are those prepared from the synthetic linear condensation polyesters, such as polyethylene terephthalate. The production of highly useful fibers composed of polyethylene terephthalate, including the steps of preparing the polymer, melt spinning the polymer to form substantially unoriented filaments, and drawing the filaments to a permanent increase in length to yield tenacious oriented fibers, is disclosed in U.S. 2,465,319 to Whinfield and Dickson. Other synthetic linear condensation polyesters may be prepared in a manner similar to polyethylene terephthalate, such as by substituting other glycols for ethylene glycol, and subsequently formed into tenacious oriented fibers. In the case of the synthetic linear condensation polyesters, it has been found that control of the orientation step is an especially critical factor in achieving uniformity of product, since small variations in the temperature and other process conditions lead to significant variations in the dyeability of the yarn and other uniformity parameters. Variations in uniformity are usually found along the length of any given yarn being processed as well as between two or more yarns which are being processed separately. In order to minimize variations in temperature, it has been proposed to carry out the orientation step in a heated bath of water or other liquid. However, it has been found that when synthetic linear condensation polyester yarns are oriented under such conditions, there is a tendency for small sections of the yarn to pass through the bath at irregular intervals without being oriented at all. Such sections of unoriented yarn are highly undesirable, since they dye to much deeper shades than the oriented sections of the yarn and show up in dyed fabrics as flecks of deep color. Unoriented sections of yarn and other uniformity defects are particularly undesirable in the case of continuous filament yarns, owing to the possibility of patterned effects attributable to the non-uniformities being formed in fabrics, since the non-uniformities are not mixed or averaged out as in the case of staple fiber.

In the case of continuous filament yarns, there has also been a desire to process more than one end of yarn on each set of feed and draw rolls, both to improve yarn uniformity by reducing the number of elements to be controlled and to improve productivity. In the past, however, this has not been considered feasible owing to the problem of straying filaments when two filament bundles are drawn in close proximity. It has also been desired to improve the physical properties of oriented yarns.

It is therefore an object of this invention to provide a novel apparatus for orienting synthetic continuous filament yarns. Another object is to provide a process for orienting continuous filament yarns composed of a synthetic linear condensation polyester in a highly uniform manner. A further object is to provide such a process in which improved physical properties of the yarn product are attained. An additional object is to provide a process for orienting a plurality of continuous filament linear terephthalate polyester yarns in a highly uniform manner. Additional objects will be apparent from the following description and claims.

In accordance with this invention the above objects are achieved with an apparatus for drawing synthetic continuous filament yarns comprising a feed roll, a draw roll adapted to be rotated at a higher surface speed than the feed roll so as to stretch a yarn passed between them, a fixed cylindrical draw pin located between the feed roll and the draw roll, and means for maintaining a liquid bath in contact with said draw pin at a level such that the bottom of the draw pin is immersed in the bath to a depth of not more than about one inch, the entry angle of the yarn into the bath being in the range of 45° to 90° and the exit angle of the yarn from the bath being in the range 75° to 85°. In a preferred embodiment of the invention, the apparatus is equipped with guides located between the draw pin and the draw roll and so disposed as to cause yarn passed between them to undergo a sharp change in direction, preferably two sharp changes in direction, so as to remove excess liquid from the yarn. Preferably, the apparatus is also equipped with guide means for maintaining a plurality of yarns at a distance of at least 0.25 inch apart from each other as they pass under the draw pin and for diverging the yarns as they leave the draw pin.

The present invention also includes a novel process which comprises, in the process of continuously orienting a synthetic linear condensation polyester yarn by passing it from a feed roll through a bath maintained at a temperature above about 75° C. and around a draw roll at a speed of at least 2,000 yards per minute, the improvement consisting of passing the yarn, in the presence of a lubricant, under a draw pin in contact with the liquid bath, the entry angle of the yarn into the bath being in the range of 45° to 90° and the exit angle of the yarn from the bath being in the range 75° to 85°. Preferably the liquid clinging to the yarn after contact with the bath is reduced to a level below about 15% and the yarn is heated after it is oriented, such as by heating the draw roll. In a preferred embodiment of the invention, a plurality of yarns of the synthetic linear condensation polyester are oriented between a common feed roll and a common draw roll in accordance with the process as described by spacing each of the said yarns at a distance of at least 0.25 inch from each neighboring yarn as the yarns pass under the draw pin and diverging the yarns as they

leave the draw pin. The process has been found to have particular utility when applied to the orientation of yarn composed of a linear terephthalate polyester.

The nature of the apparatus and process of the present invention will be more fully understood with reference to the accompanying drawings, in which

FIGURE 1 is a somewhat diagrammatical side view of the apparatus of the present invention;

FIGURE 2 is a detailed side view of the draw pin illustrating the critical relationship of yarn contact angles and liquid level prevailing at the draw pin, together with additional pin elements which are used with the apparatus in a preferred embodiment of the invention; and

FIGURE 3 illustrates the draw pin as viewed from above, showing the critical spacing and divergence of a plurality of yarns as they pass under the draw pin.

Referring now to FIGURE 1, undrawn yarn **1** is supplied to feed roll **2** from a suitable source (not shown), preferably by being forwarded directly from a spinneret from which the yarn is being produced by the extrusion of a plurality of filaments together. To prevent slipping, several wraps are usually taken around the feed roll together with its associated separator roll **3**, the axis of which is usually slightly canted from that of the feed roll to assure separation of each wrap from the preceding wrap. The yarn is then passed under cylindrical draw pin **4** and, without being passed over the top of the pin to complete one or more wraps, is passed on to draw roll **5** and its canted separator roll **6**. After taking several wraps around the draw roll and its separator roll, the yarn is wound up on a suitable package (not shown). The draw roll is preferably adapted to be heated so that the shrinkage of the yarn may be reduced by crystallization of the polymer in the yarn; or, if desired, separate heated rolls (not shown) between the draw roll and the windup may be supplied to reduce the shrinkage of the yarn. If separate heated rolls are used, they may be operated at the same surface speed as that of the draw roll, or higher or lower speeds may be used to stretch or relax the yarn, respectively. A tank **7** containing a bath **8** of liquid is provided in contact with the draw pin. The liquid is introduced through inlet tube **9** having a closed end **10** but provided with perforations **11** through which liquid flows continuously into the bath. Liquid is removed continuously from the bath through overflow tube **12**, by means of which the liquid level **13** is readily maintained constant with respect to the draw pin **4**. The liquid is normally recirculated from overflow tube **12** to inlet tube **9** through a reservoir, not shown, which is desirably maintained at constant temperature. The tank is provided with a top or cover **14** to minimize evaporation of the liquid. Slots **15** and **16**, through which the yarn enters and leaves the bath, extend to one side of the cover so that the cover may be placed in position after the apparatus has been strung up.

Between the draw pin and the draw roll, the yarn is passed around cylindrical guide pins or stripper pins **17** and **18**, which are so disposed with respect to the draw pin and draw roll that the yarn is caused to undergo a sharp change in direction. Sharply changing the direction of yarn travel in this way causes the liquid which normally clings to the yarn to become separated from the yarn as spray, so that the yarn contains less than about 15% of the liquid. Spray container **19**, consisting of a shield **20** mounted above the draw pin approximately parallel to the yarn as it leaves the pin and extending across and downward to the top of the tank to form a receptacle, serves to collect the liquid which is sprayed from the yarn through opening **21** in the cover above the first stripper pin **17** as the rapidly moving yarn changes direction. The collected spray is returned to bath **8** through drain **22**.

By causing excess liquid to be removed from the yarn and returned to the bath recirculation system in accordance with the invention as described above, the heat load on heated draw rolls or other heated rolls is greatly reduced. Staining of the yarn, attributable to contact with the yarn by spray droplets having a higher concentration of finish oils than the bath itself as the result of evaporation of water from the droplet, is also avoided.

Certain elements of the apparatus and process of the invention have been found to be highly critical. The draw pin and the liquid bath are such elements, since in the absence of either the high degree of uniformity of yarn product achievable with the present invention is not attained. However, in order to achieve the desired results, there are additional critical relationships. Turning now to FIGURE 2, the depth d to which the draw pin is immersed in the liquid bath is no more than about one inch; when a deeper immersion of the draw pin is made, the process frequently becomes inoperable. In general the draw pin should be immersed about half its diameter in the bath. Draw pins of small diameter may be completely immersed. Moreover, in accordance with the invention, the entry angle α of the yarn into the bath is in the range 45° to 90° and the exit angle β of the yarn from the bath is in the range 75° to 85° C. Maintenance of the entry angle within the range 45° to 90° permits wetting of the yarn as it contacts the draw pin without an excessive tension drop as it enters the water; while an exit angle in the range 75° to 85° is highly important in precluding foam formation and permitting easy collection of spray. At smaller exit angles the amount of liquid carried along with the yarn is also greatly increased.

In accordance with the invention, the yarn is passed under the pin but is not wrapped completely around the pin. The arc around the circumference of the pin through which the yarn travels is therefore in the range of about 120° to 175°. When the yarn is passed through greater arcs, excessive tension is encountered and nonstable filament action is observed on the feed roll with resulting poorer yarn denier uniformity. The diameter of the draw pin is usually in the range of about 0.25 to 2 inches. Although the draw pin will usually be a right circular cylinder in form, it may be a cylinder having a convex curved cross section other than circular, such as an elliptical cross section.

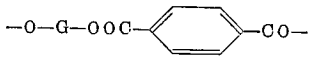
In a highly preferred embodiment of the invention, the process is applied to a plurality of yarns being oriented between a common feed roll and a common draw roll. As shown in FIGURE 3, a plurality of parallel yarns **1'** are passed in a series of wraps around feed roll **2** and canted separator roll **3** and thence to draw pin **4**. Between the feed roll and the draw pin the yarns pass between a set of guides **23**, which may be vertical pins, set to maintain a distance of at least 0.25 inch between each yarn and its neighboring yarns. After leaving the draw pin, the yarns pass through a second set of vertical pins **24** or other guides which are set at a wider spacing than the guides **23**, so that the yarns are caused to diverge. The yarns are then passed to draw roll **5** and its canted separator roll **6**, as in FIGURE 1. For convenience, stripper pins **17** and **18** for stripping the excess liquid from the yarn, as well as certain other elements of the preferred apparatus, are omitted from FIGURE 3.

Surprisingly, although the degree of divergence may be very slight, the requirement for divergence is critical even when spacings wider than the minimum operable spacing of 0.25 inch are employed. Even slight convergence of the yarns is found to result in the formation of fluff balls and in the occurrence of broken filaments. This apparently results from the fact that, when the yarns are converged, liquid from the bath is carried in a sheet between the yarns, promoting migration of filaments between yarns. When a filament migrates, it is broken as the yarn passes the next set of guides and the broken filament then strips back until the resulting fluff ball breaks down the entire yarn. Although maintenance of the yarns in parallel relationship leads to better results than convergence, in practice it is found

very difficult to produce true parallelism. Accordingly, it is preferred to diverge the yarns, since no liquid sheet is formed between diverging yarn ends and migration of filaments is avoided.

The liquid bath, which may be any non-solvent for the synthetic linear condensation polymer of which the yarn is composed, should be maintained at a temperature of at least about 75° C. to ensure uniform orientation of the yarn. At lower temperatures small sections of unoriented yarn, which represent a severe non-uniformity problem, are frequently observed in the product. Bath temperatures in excess of about 150° C. are usually avoided. Preferably, an aqueous bath maintained at a temperature in the range of about 75° to about 100° C. is used. The presence of a lubricant, which may be any suitable liquid which maintains itself in film form between the moving yarn and the draw pin, is also important. Any suitable textile lubricant or finish may be employed. Commercially available textile finishing agents which may be used include aqueous solutions of cationic alkyl fatty amine derivatives, sodium cetyl sulfate, and sodium salts of saturated hydrocarbon sulfonates; for typical examples see "Encyclopedia of Surface Active Agents," by Sisley and Wood, page 232, col. 1, lines 6 and 27, and col. 2, line 4. In certain non-aqueous baths, such as a silicone oil, the liquid comprising the bath may itself serve as the lubricant. In the case of aqueous baths, a suitable liquid lubricant may be dispersed in the bath. As another alternative, the lubricant may be applied to the yarn before the yarn contacts the bath.

Although the invention may be applied to various linear condensation polyesters, it is especially suitable for the orientation of yarns composed of the linear terephthalate polyesters, the preferred species of the invention. By "linear terephthalate polyester" is meant a linear condensation polyester comprising recurring glycol dicarboxylate structural units in which at least about 75% of the recurring structural units are units of the formula



wherein —G— represents a divalent organic radical containing from 2 to about 18 carbon atoms and attached to the adjacent oxygen atoms by saturated carbon atoms. Preferably, the radical —G— contains from 2 to about 10 carbon atoms. The terephthalate radical may be the sole dicarboxylate constituent of the recurring structural units, or up to about 25% of the recurring structural units may contain other dicarboxylate radicals, such as the adipate, sebacate, isophthalate, bibenzoate, hexahydroterephthalate, 2,6- or 2,7-naphthalenedicarboxylate, diphenoxyethane-4,4'-dicarboxylate, p,p'-carbonyldibenzoate, and p,p'-sulfonyldibenzoate radicals. The linear terephthalate polyesters may be prepared by reacting terephalic acid or a mixture of terephthalic acid and one or more other dicarboxylic acids with a glycol, $G(OH)_2$, where —G— is a radical as defined above, to form the bis-glycol ester or mixture of esters, followed by polycondensation at elevated temperature and reduced pressure with elimination of excess glycol. In place of the acid or acids, ester-forming derivatives may be used, i.e., derivatives which readily undergo polyesterification with glycol or derivative thereof. For example, the acid chloride or a lower alkyl ester, such as the dimethyl ester, may be used. Similarly, an ester-forming derivative of the glycol may be used in place of the glycol; i.e., a derivative of the glycol which readily undergoes polyesterification with dicarboxylic acids or derivatives thereof. For example, a cyclic oxide from which the corresponding glycol can be derived by hydrolysis may be used.

The glycol, $G(OH)_2$ from which the polyester is prepared may be any suitable dihydroxy compound containing from 2 to 18 carbon atoms, preferably from 2 to 10 carbon atoms, in which the hydroxyl groups are attached to saturated carbon atoms. Examples of suitable glycols include the polymethylene glycols, such as ethylene glycol, tetramethylene glycol, hexamethylene glycol, and decamethylene glycol as well as the branched chain glycols such as 2,2-dimethyl-1,3-propanediol and 2,2-dimethyl-1,4-butanediol. Other suitable glycols include cis- and trans-p-hexahydroxylylene glycol, bis-p-(2-hydroxyethyl)-benzene, diethylene glycol, bis-(4-hydroxybutyl)ether, bis-1,4-(2-hydroxyethoxy)benzene, and triethylene glycol. Mixtures of the glycols may be used. If desired small amounts, e.g. up to about 15 weight percent, of a higher glycol such as polyethylene glycol of high molecular weight may be added. A copolyester may also be formed by replacing part of the terephthalic acid or derivative thereof with a hydroxy acid or derivative thereof, such as p-(2-hydroxyethyl)benzoic acid or methyl 4-(2-hydroxyethoxy)benzoate.

The following examples illustrate the principles and practice of this invention, although they are not intended to be limitative. The presence of "flashes," or segments of undrawn filament in the yarns, is determined by weaving a few quills of the test yarn into a filling fabric using standard warp yarns, followed by dyeing the fabric with Celanthrene Brilliant Blue FFS dye (C.I. No. 61505). The filling of the fabric is then examined for the presence of flashes, which are readily observed owing to the greater affinity of the flashes for dyes than is exhibited by the remainder of the yarn.

In the examples, numerical values for wet crease recovery, an important fabric parameter, refer to the Monsanto Crease Recovery Method, described as the "vertical strip crease recovery test" in the American Society for Testing Material Manual, Test No. D1295–53T. In determining wet crease recovery by this method, the specimens are soaked for at least 16 hours in distilled water containing 0.5% by weight of "Tween 20," a polyoxyalkylene derivative of sorbitan monolaurate, a wetting agent marketed by the Atlas Powder Company, Wilmington, Delaware. Immediately prior to testing, excess water is removed from the test fabric by blotting between layers of a paper towel. Results are reported as percent recovery from a standard crease in 300 seconds.

Yarn uniformity values are determined with the Uster Evenness Tester, Model C, sold by Zellweger Ltd., Uster, Switzerland, which measures variation in denier electronically by means of a capacitance gauge (ref.: "Evenness Testing," by P. W. Mullen, Textile Industries, vol. 7, p. 118 ff., July 1953). Uster values as reported are percentage unevenness values, based on the deviation from the average value.

Example 1

Polyethylene terephthalate having a relative viscosity of 27 is spun at 290° C. through a spinneret plate containing 136 round orifices. The filaments are gathered as four separate yarn bundles of 34-filament yarn and lubricated with a commercially available textile finishing agent comprising a cationic alkyl fatty amine derivative. The yarns are then passed from a feed roll and an associated separator roll at 660 yards per minute vertically downward and under a draw pin ½ inch in diameter, and then upward at an angle of 82° to a stripper pin ⅜ inch in diameter. The apparatus employed is of the type shown in FIGURE 1. The draw pin is immersed to a depth of ¼ inch in an aqueous bath containing 1% of the alkyl fatty amine derivative finishing agent and maintained at 90° C. The yarns are passed over the first stripper pin at an angle of about 90°, under a second pin at about the same angle, and are then wrapped around a pair of heated rolls maintained at 130° C. and operated at 2750 yards per minute surface speed, after which they are finally wound on a suitable package. The four ends of yarn are separated by spacings of 0.25 inch as they pass under the draw pin and are diverged as they leave the pin as shown in FIGURE 3. The con-

tact arc of the yarn under the draw pin is approximately 172°. The draw ratio applied to the yarn is 4.16 and the drawn yarn has a denier of 70 per end (7.8 tex). The yarn has a tenacity of 4.1 g.p.d., an elongation of 27%, an initial modulus of 104 g.p.d., a boil-off shrinkage of 7.6%, and a Uster value of 1.0% for denier uniformity. The yarn exhibits no "flashes" when woven and dyed. Woven samples of the yarn exhibit a Monsanto crease recovery value of 62%.

When the pair of stripper pins following the draw pin are removed and the experiment is repeated, excessive moisture carry over on the yarn occurs and the heated rolls are found to be incapable of producing yarn having equivalent shrinkage and other physical properties.

Example 2

Polyethylene terephthalate having a relative viscosity of 25.5 is spun at 290° C. through a spinneret plate containing 100 round orifices. The filaments are gathered as two separate yarn bundles of 50-filament yarn and lubricated with a commercially available textile finishing agent comprising a cationic alkyl fatty amine derivative. The yarns are then passed from a feed roll at 670 yards per minute, around a one-inch ceramic draw pin (wrap angle 450°), around a pair of stripper pins with a sharp change in direction, around a pair of heated rolls maintained at 130° C. and operated at 2750 yards per minute surface speed, and are finally wound on a suitable package. The two ends of yarn are separated by a spacing of 0.25 inch as they pass around the pin and are diverged as they leave the pin. The pin is immersed 0.5 inch in a bath of water containing the alkyl fatty amine derivative finishing agent maintained at 95° C. The draw ratio applied to the yarn is 4.1 and the drawn yarn has a denier of 250 per end (26.7 tex). The Uster value obtained with yarn produced in this way is 1.9%, which is considered poor from the standpoint of denier uniformity. As noted in Example 1, superior results are obtained by employing a wrap angle of only 172°.

Example 3

Polyethylene terephthalate/5-(sodium sulfo)isophthalate (98/2) having a relative viscosity of 19.5 is spun at 290° C. through a spinneret having 34 orifices. The filaments are gathered as a single yarn bundle and lubricated with a commercially available textile finishing agent comprising a cationic alkyl fatty amine derivative. The yarn is then passed from a feed roll at 675 yards per minute through a simple weir or flume bath to a pair of heated rolls operating at 2025 yards per minute surface speed and maintained at 130° C. and thence to a windup package. The bath is composed of an aqueous solution of the alkyl fatty amine derivative finishing agent maintained at 98° C. The draw ratio is 3.0 and the denier of the drawn yarn is 70 (6.7 tex). Filling fabrics woven from the yarn are found to contain "flashes" and streaks in the filling when the fabrics are dyed with Celanthrene Brilliant Blue FFS dye.

The experiment is repeated, employing the draw pin apparatus of Example 1 under the operating conditions described therein. Filling fabrics woven from the yarn are found to be highly uniform when dyed with Celanthrene Brilliant Blue FFS dye, with no streaks or "flashes" in the filling.

Example 4

The experiment of Example 1 is repeated, except that the ends of yarn are separated by spacing of 0.25 inch as they pass under the pin (yarn contact arc 120°) and are converged to spacings of 0.125 inch at the first guide following the draw pin. Operation of the process under these conditions results in the formation of fluff balls and broken filaments, preventing successful drawing.

The experiment is repeated with a separation of the ends by spacings of 0.375 inch at the first guide following the draw pin, so that the yarns are diverged as they leave the draw pin. Operation of the process is satisfactory with no fluff balls or broken filaments being observed.

The apparatus and process herein disclosed result in synthetic linear condensation polymer yarns which have surprisingly good uniformity when dyed. They are particularly free from flashes and other types of unevenness. The invention offers as a further advantage improved uniformity of finish together with satisfactory spinning speeds.

It will be apparent that many widely different embodiments of this invention may be made without departing from the spirit and scope thereof, and therefore it is not intended to be limited except as indicated in the appended claims.

I claim:

1. An apparatus for drawing one or more yarns of synthetic linear condensation polymer filaments comprising a rotatable feed roll, a horizontally disposed draw pin, and a draw roll adapted to be rotated at a higher surface speed than the feed roll so that yarn passing from the feed roll under the draw pin to the draw roll is drawn; means for maintaining a liquid bath in contact with the said draw pin; a stripper pin located above the said draw pin between it and the draw roll and positioned to establish an abrupt angle in the path of the yarn between the draw pin and the draw roll; means including the feed roll and the draw roll for passing the yarn at a high rate of speed in non-converging relation under the draw pin and through the liquid and thence upwardly over the stripper pin whereby the liquid taken up by the yarn from the bath leaves the yarn as a spray as the yarn passes over the stripper pin; and means for collecting the liquid spray.

2. The apparatus of claim 1 which includes a spinneret and means for passing the polymer in molten condition through the spinneret to form a multifilament yarn and for passing the said yarn continuously to said feed roll.

3. The apparatus of claim 1 in which the feed roll and stripper pin are located in a position such that the yarn is fed at an angle between 45° and 90° from the horizontal to the draw pin and leaves the draw pin at an angle between about 75° and 85° from the horizontal, and the contact angle between the yarn and draw pin is from 120° to 175°.

4. The apparatus of claim 3 in which the surface of the bath is maintained not more than about one inch above the lower surface of the draw pin.

5. In the process of orienting one or more yarns of synthetic linear condensation polymer filaments by passing the yarn in non-converging relation from a feed roll under a draw pin immersed in a liquid to a draw roll rotating at a higher peripheral speed than the feed roll, whereby the yarn is drawn, the improvement which comprises changing the direction of the yarn abruptly between the draw pin and the draw roll by passing it over but not around a stripping pin whereby liquid entrained by the yarn is removed as a spray; and collecting said spray.

6. The process of claim 5 in which the liquid is maintained at a temperature between about 75° C. and about 150° C.; the entry angle of the yarn to the draw pin is maintained at an angle of about 45° to 90° from the horizontal; and the exit angle of the yarn as it leaves the draw pin is maintained at an angle of about 75° to 85° from the horizontal, the angle of contact between the yarn and draw pin being from about 120° to 175°.

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