Oct. 24, 1961 C. E. HALLDEN, JR., ET AL 3,005,251

YARN FLUID TREATMENT PROCESS AND APPARATUS

Filed Dec. 19, 1958 2 Sheets-Sheet 1

Fig. 1

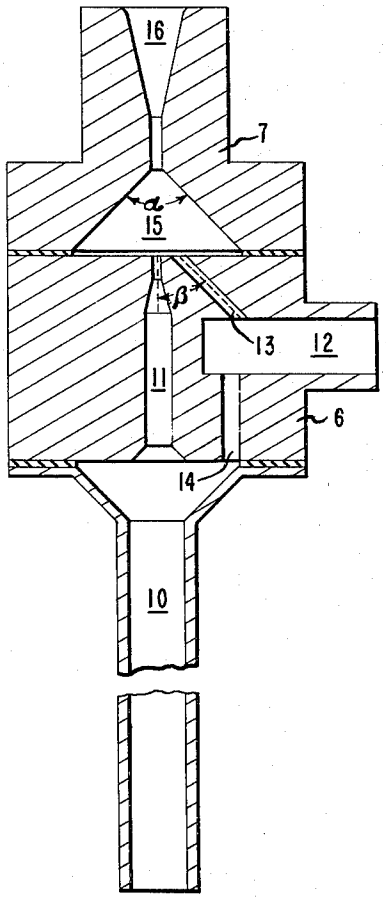


Fig. 2

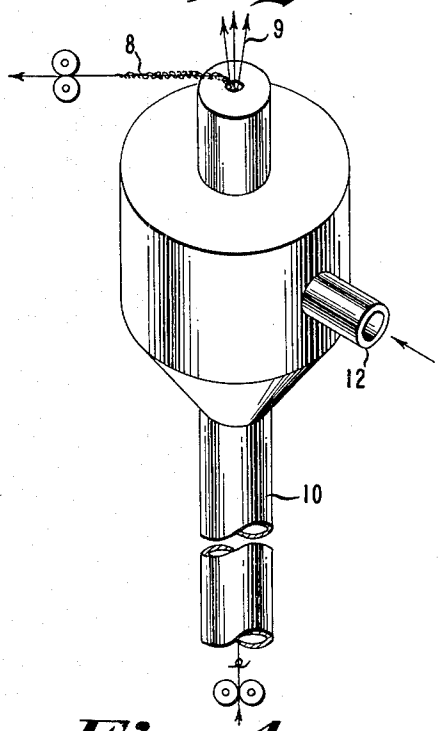


Fig. 3

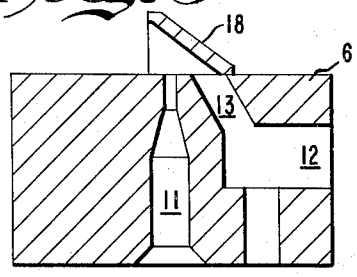
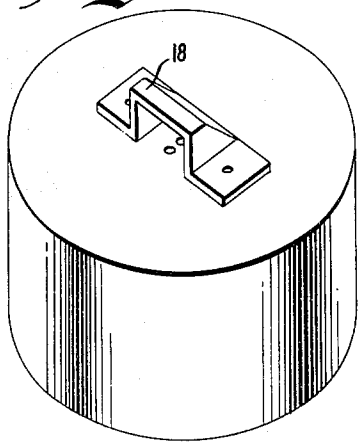


Fig. 4



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YARN FLUID TREATMENT PROCESS AND APPARATUS

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Fig. 5

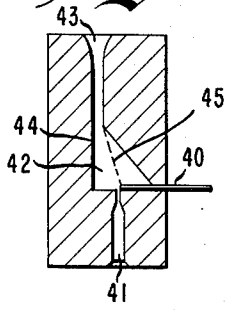


Fig. 6

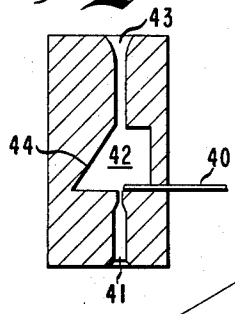
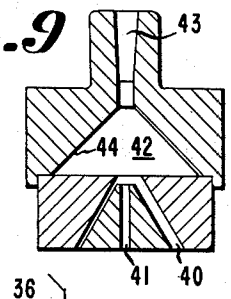


Fig. 9



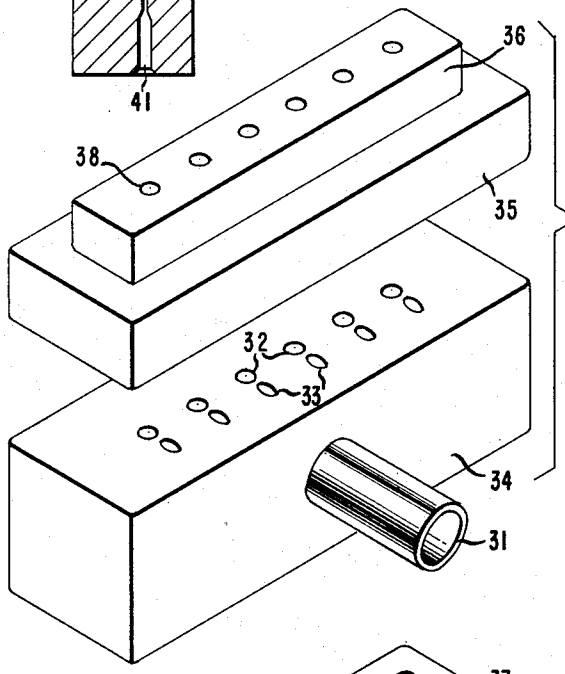
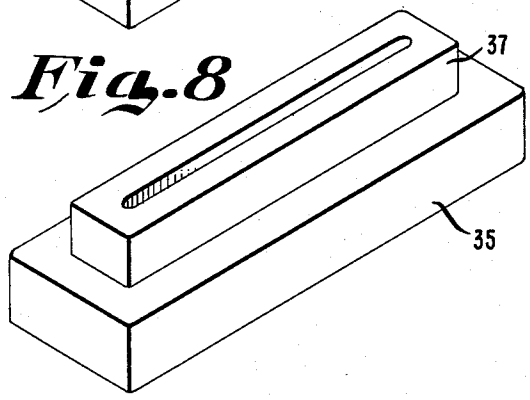


Fig. 7

Fig. 8



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YARN FLUID TREATMENT PROCESS AND APPARATUS

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Filed Dec. 19, 1958, Ser. No. 781,549
13 Claims. (Cl. 28—1)

This invention relates to a process and apparatus for treating a bundle of filaments such as yarn or thread to produce a multifilament yarn of greatly increased tenacity and dyeability. More particularly, the invention relates to a process and apparatus for producing a bulky yarn composed of a plurality of individually crimped filaments having a random three-dimensional curvilinear configuration, high tenacity, and improved level dyeing characteristic and faster dyeing rate.

Artificial fibers are normally produced most easily as continuous filaments. These continuous filament yarns are very strong because of the absence of loose ends that are unable to transmit imposed stresses. Their extreme uniformity and lack of discontinuity, however, makes conventional continuous filament yarns much more dense than yarns made from staple fibers. The production of yarn from staple fibers, however, is time-consuming and requires a complex series of operations to crimp the fibers, align the fibers into an elongated bundle and then to draw the bundle to successively smaller diameters. The final spinning operation, which involves a high degree of twist, finally binds these discontinuous fibers together to produce a coherent yarn with considerably increased bulk. The occluded air spaces give them a lightness, covering power, and warmth-giving bulk not normally possible with continuous filament yarns. Thus, to get staple fibers that can be processed on conventional wool or cotton spinning equipment, it has been the practice to cut continuous filament yarns such as rayon, acetate, nylon, as well as the polyacrylic and polyester fibers into short lengths for spinning into staple yarn.

Recent developments in the textile industry have provided useful routes for improving the bulk and covering power and recoverable elongation of continuous filament yarns without resorting to the staple spinning systems of the prior art. A well-known process for making stretch yarn involves the steps of twisting, heat-setting and then backtwisting to a low final twist level. Another yarn of improved bulk is prepared commercially by the steps of twisting, heat-setting and backtwisting on-the-run using a false-twisting apparatus. This end product can be further modified by hot relaxing to improve the bulk and handle. Still another bulk yarn is being prepared by the well-known stuffer box technique wherein the yarn is steamed to heat-set while it is in a compressed state in the stuffer box.

All of these yarns of the prior art are produced by a process which has the common elements of deforming the yarn mechanically and then heat-setting either with or without an after-relaxation step. It was not until the recenly disclosed product in U.S. 2,783,609 to Breen and its process of manufacture became known that an entirely new technique became available for improving the bulk of continuous filament yarns. This technique involves exposing a filamentary material to a rapidly moving turbulent fluid, thereby inducing a multitude of crunodal filament loops at random intervals along the individual filaments. These loops and snarls of entangled loops increase the bulk of the continuous filament yarns considerably and result in fabrics of improved cover, bulk, handle, and the like. With the invention of Breen, a new tool is

available for the bulking of filamentary structures, i.e., a turbulent fluid. Fluids, of course, have been used for yarn treating in many of the prior art operations such as drying, extracting, transporting, and the like. Until the invention of Breen, however, they had not been used to entangle, convolute, and bulk a filamentary material. It has now been discovered, however, that a new process utilizing the turbulent fluid technique results in new yarn products that have certain unique properties not heretofore disclosed in the art.

It is an object of the present invention, therefore, to provide continuous filaments and continuous filament yarn having a bulkiness greater than staple yarn spun from comparable fibers. Another object is to provide multifilament yarn resembling spun staple in its desirable lightness, covering effectiveness and warmth-giving bulk but retaining the characteristic continuous filament freedom from loose ends, fuzziness, and pilling. It is also an object to prepare a bulky filamentary material especially useful for the pile component of pile fabrics. It is another object to provide both crimped and uncrimped synthetic organic filamentary strands having high tenacity and an unusually high rate of dyeability. It is another object to provide apparatus which is peculiarly suited for carrying out the above-described process and producing the above-described products. Other objects will appear hereinbelow.

According to this invention there is provided synthetic organic filamentary strands having high tenacity and a rate of dyeability which has not been attained heretofore. These products are produced by feeding a synthetic organic filamentary strand at an overfeed of at least about 12% to a plasticizing stream of a compressible fluid in which the individual filaments, while in a plastic state, are momentarily separated from each other and then cooled. The strand may be cooled by passing through air at normal room temperature. The product has high tenacity and also possesses a rate of dyeability at least about 75% greater than that of the feed strand. By increasing the overfeed to at least 30%, preferably at least 40%, the filamentary product produced contains, in addition to the high tenacity and high rate of dyeability set forth above, fibers possessing an independent random, persistant, three-dimensional non-helical curvilinear configuration along the line of the filamentary strand and is substantially free of stable crunodal loops.

The process and apparatus of this invention represent a substantial improvement over known methods and equipment for bulking yarn not only because of the superior quality of the products produced, but also because of the high rate of production which the process and apparatus makes possible. The invention and the manner of carrying it out will be more clearly understood by reference to the drawings in which,

FIGURE 1 is a sectional view of a preferred embodiment of the apparatus of this invention.

FIGURE 2 is a perspective view of the apparatus of FIGURE 1.

FIGURE 3 is a sectional view of a preferred embodiment of the supply portion 6 of the apparatus of FIGURE 1.

FIGURE 4 is a perspective view of the apparatus of FIGURE 3.

FIGURES 5 and 6 are sectional views of alternate apparatus which may be utilized in this invention.

FIGURE 7 is an exploded view of an apparatus suitable for handling a number of individual yarn ends simultaneously.

FIGURE 8 is another embodiment of such an apparatus for handling multiple yarn ends in the form of a warp sheet or the like.

FIGURE 9 illustrates another useful embodiment of the apparatus.

In FIGURE 1 the treating apparatus includes a housing formed of a lower section 6 and an upper section 7. The yarn enters preheating assembly 10 and then passes through the yarn introducing means 11 in housing section 6 to bulking chamber 15 in the shape of a cone having housing section 6 as a base, the conical surface being formed in upper housing section 7. Yarn introducing means 11 is slightly larger in diameter than the greatest diameter of the strand to be processed to avoid substantial impedance of yarn movement A fluid plasticizing medium enters chamber 15 at high velocity (at least ½ sonic) from a suitable manifold 12 through the fluid injection passage 13 in lower housing 6 and forces the rapidly moving threadline out of its original path so that both impinge against the side of chamber 15. The filamentary material is then removed through the venturi throat 16 in upper housing 7 along with fluid. The treated yarn after issuing from the venturi throat at 16 is forwarded at a controlled rate to a windup.

In FIGURE 2 yarn is shown being fed to preheating assembly 10 by feed rolls and a pigtail guide while fluid enters manifold 12. Yarn product 8 is withdrawn by advancing rolls from fluid exhaust 9. This apparatus is at least 50% more efficient than prior known apparatus for heating yarn with fluids as allowing a much higher rate of processing without reducing yarn product quality.

A preferred embodiment of the apparatus of this invention is shown in FIGURES 3 and 4. These views show the relative positioning of an auxiliary baffle 18 which is inclined over the exit of the fluid injection passage 13 and yarn introducing passage 11. This baffle concentrates the fluid plasticizing stream on the yarn bundle immediately at the point of entry of both into treating chamber 15 and substantially improves the efficiency of heat and energy transfer from the fluid to the yarn bundle. The process of this invention is about 50% more efficient than the apparatus of FIGURE 1 without baffle 18.

FIGURES 5 and 6 are alternative embodiments of apparatus suitable for the process of this invention. Fluid passageway 40 and yarn passageway 41, respectively, terminate in chamber 42 and impinge on solid surface 44 under the driving force of the fluid medium. Venturi outlet 43 may be positioned as shown or in any suitable alternate position relative to passageways 40 and 41 but will generally be as shown. The treating chamber wall or other obstacle surface can also have varied positions as shown by these figures and dotted line 45. Other possibilities of angled walls and treating chamber shapes will be obvious to those skilled in the art.

FIGURE 7 shows a species of apparatus suitable for the handling of multiple ends of yarn and contains the same elements shown in FIGURE 1 with some slight modifications for ease of fabrication, string-up, and multiple end operation. Steam enters body 34 through manifold 31 and is distributed to a plurality of fluid injection passageways 33 through suitable distribution means. Yarn is introduced by suitable means through yarn passageways 32 into a common treating chamber contained in block 35. The individual ends of crimped yarn then pass through the venturi outlets 38 located in head 36.

FIGURE 8 shows another form of venturi unit that can be used in place of block 35 in FIGURE 7 above. This modification has certain advantages with reference to ease of string-up when processing multiple ends of yarn in the form of a warp sheet or the like through the fluid jets of this invention. The fluid injection and yarn passageways can also be slots rather than the individual elements shown at 32 and 33 in FIGURE 7.

In FIGURE 9 fluid inlet 40 surrounds yarn inlet 41 but the latter is eccentric in the fluid inlet so that pressure against incoming yarn by jetting fluid is not uniform and the yarn is diverted from its normal path by the unbalanced force on the yarn and forced to impinge against the wall 44 of treating chamber 42. Similarly, both yarn and fluid may be introduced into the chamber concurrently from a single tubular inlet so long as it is forced to impinge upon a suitable obstacle surface within the treating chamber, preferably one inclined directly in the path of the incoming yarn and fluid so that the direction of the yarn and fluid is changed thereby prior to exiting from the treating chamber by a conical or venturi shaped outlet.

In a preferred embodiment of this invention a plasticizing fluid at high velocity is directed against a moving filamentary strand so that the yarn is forced against a solid obstacle which abruptly changes the direction of movement of both the strand and the fluid. The strand is then removed from the treating chamber by the moving fluid while the latter undergoes a controlled gradual expansion. At overfeeds of between 12% and about 30% the product is uncrimped but still possesses the astonishingly high dyeability rate and tenacity characteristics of the crimped product. At strand overfeeds of at least about 30% the plasticizing fluid softens the filamentary material, furnishes the energy necessary to accomplish filament crimping, as well as removing the crimped product from the treating chamber. While removing this crimped product, the treating fluid undergoes a controlled gradual expansion which serves the auxiliary purpose of initiating cooling of the product and reducing fluid velocity, thereby eliminating undue tension on the yarn. This controlled expansion of the plasticizing fluid as it leaves the treating chamber is preferably accomplished by passing both strand and fluid through a conical or venturi section, although a suitable baffle may sometimes be used. This conical section (frustum), which, of course, has its widest end downstream, has a taper between 3° and 45° with the preferred limits of 5° and 15°. As shown in FIGURE 1, the yarn to be treated is usually fed at a controlled rate as may be determined by the rolls between which it passes on its way into the jet. Details of the processing conditions are disclosed in copending application Serial Nos. 698,103, filed November 22, 1957, and 772,475, filed November 7, 1958, now abandoned, by Breen and Lauterbach.

The process and apparatus of this invention can be used to crimp and bulk any natural or synthetic plasticizable filamentary material. Thermaplastic materials such as polyamides, e.g., poly(epsilon caproamide), poly(hexamethylene adipamide); cellulose esters; polyesters, e.g., polyethylene terephthalate, poly(hexahydro-p-xylylene terephthalate), etc.; polyvinyls and polyacrylics, e.g., polyethylene and polyacrylonitrile, as well as copolymers thereof can be crimped to give the three-dimensional, random, curvilinear configuration described herein. While the preferred form of material is continuous filaments, the process and resultant improvements occur with staple yarns as well. Both types of materials can be made into bulky yarns and fabrics having improved bulk, covering power (opacity) and hand.

This apparatus and process are useful for both monofilament yarns in textile deniers as well as the heavier carpet and industrial yarn sizes either singly or combined in the form of a heavy tow. Fine count and heavy count staple yarns can be processed both singles and plied. The process and product are also not restricted in the case of the synthetic materials to any one particular type of filament cross section. Cruciform, Y-shaped, delta-shaped, ribbon, and dumbbell and other such filamentary cross sections can be processed at least as well as round filaments and usually contribute still more bulk than is obtained with round filaments. By proper design of the jet and process, multiple ends of yarn may be handled either in the form of warp sheets, ribbons, or tows.

The turbulent fluid used to treat the filamentary material may be air, steam, or any other compressible fluid or vapor capable of plasticizing action on the yarn pro-

vided that it has a temperature above the second-order transition temperature of the filament. Preferably the temperature is above 300° F. Hot air will give sufficient plasticization in the turbulent region for many fibers although it may be desirable for certain fibers to supplement the temperature effect with an auxiliary plasticizing medium. Actually, steam is preferentially used in the subject process since it is a cheap and convenient source of a high pressure fluid with a compound plasticizing action.

The temperature of the fluid medium must be regulated so that the yarn temperatures do not reach the melting point of the fiber. However, with fibers made from fusible polymers, the most effective bulking and the greatest productivity is obtained when the temperature of the turbulent fluid is above the melting point of the fiber. In this case the yarn speeds should be great enough so that melting does not occur. Because of the great turbulence and the high heat, yarns are heated rapidly. Temperatures lower than the second-order transition temperature (T_g) of the yarn material should usually not be employed because under these conditions any crimping or bulking of the filaments is not permanent and utility of the fibers is reduced.

The process usually operates at temperatures in excess of the melting or degradation temperature of the yarn being treated, especially at high rates of yarn throughput. The threadline during string-up should be kept moving at a rate approximate to that achieved in operation. There are a number of suitable means for achieving this string-up "on-the-run"—one of the simplest being the use of a sucker gun to start the yarn through the jets. Preferably, as shown in FIGURE 2, yarn is removed abruptly from the plasticizing fluid as it leaves the apparatus.

For high speed operation, it is frequently desirable to preheat the yarn bundle prior to its entry into the treating chamber of the subject invention. This preheating can be accomplished by any number of means, one of the simplest being that shown in FIGURES 1 and 2. Here some of the fluid plasticizing medium is diverted through passageway **14** into the yarn preheater **10** where it passes in a direction countercurrent to the yarn bundle and effectively preheats the yarn to minimize the heat load requirements in trating chamber **15**. Other forms of preheaters can take the form of heated rolls, hot plates, infrared radiation, and many others commonly known in the art. Either post heating or post cooling can be utilized on the yarn immediately after it emerges from the venturi to modify, or improve the crimped and convoluted configuration of the filaments in the yarn bundle. Use of preheating, precooling, or a combination depends on the physical characteristics and fiber morphology of the filamentary material being treated, as well as the finished product desired.

The configuration and accompanying characteristics of yarn treated by the apparatus of this invention depend in part upon the amount and velocity of the fluid plasticizing medium, the various features of the jet construction, temperature, yarn speed, and the fiber being treated. A further description of the products that can be prepared using the subject apparatus as well as alternative processes are described in copending application Serial No. 698,103, filed November 22, 1957, by Breen and Lauterbach. The desirable bulkiness and other attributes of yarns as treated herein are discussed in the above application.

It is desirable to have the various yarn passageways made of especially hard material to reduce wear. These yarn passageways may be made of high-carbon steel of great hardness while the remainder of the housing may be of softer material such as ordinary stainless steels or even brass. It may be desirable for the passageways to carry hardened inserts because of the wear potential from abrasion by the filamentary bundle. There are a number of suitable ceramic materials available on the market for this purpose.

For the optimum bulking of specific yarns, the jet parameters have to be carefully determined. The size of the yarn hole **11** as well as that of the venturi exit **16** (see FIGURE 1) depends upon the type and denier of yarn that is to be processed. The yarn introducing tube at **11** should be just large enough to allow passage of the yarn being treated. The exit at **16** must be large enough to allow the crimped yarn to exit without imposing excess tension on the yarn bundle as well as the passage of the plasticizing fluid itself from the treating chamber. The plasticizing fluid inlet **13** has to be of sufficient size to deliver an adequate amount of plasticizing fluid. The length to diameter ratio of the fluid inlet is important since the low ratios which are preferred have a considerable beneficial influence upon the force distribution to the yarn bundle. For high efficiency it is preferred that any gap between the yarn and the fluid introducing passageway be kept as small as possible.

In the embodiment shown in FIGURE 1, the angle adpha in the treating chamber **15** is critical. The chamber is preferably in the form of a right circular cone and the angle alpha may vary from 60° to 120° depending upon the specific design of treating apparatus and material being. treated. In a preferred species this angle is $90°\pm10°$.

Another important variable of the above embodiment of the yarn treating apparatus is the angle beta between the axis of the yarn introducing means **11** and the axis of fluid passage **15**. The angle beta can be varied, depending upon characteristics desired in the process and product, from 20° to 70° with a preferred range from 25° to 45°.

In the preferred species of the apparatus the yarn introducing and the fluid passageway will have axes in the same plane. This achieves maximum effectiveness in applying the kinetic force of the treating fluid to the moving threadline. When the fluid passageway is off-center in circular jets, some torque action may result. In non-circular jets, excessive turbulence may result and/or inefficient transfer of kinetic and heat energy to the moving threadline may occur. The treating chamber is preferably in the shape of a cone as indicated in FIGURE 1 but may be any other suitable configuration such as spherical, cubic, tetrahydral, octahedral, etc., and generally the average height of the treating chamber should not be substantially less than about one-third of the average width. Perferably, the treating chamber will have a volume between about 1 and about 10 times that of a sphere having a diameter equal to the sum of the diameters (or the equivalent) of the yarn and fluid inlets at the point of interception of these inlets with the treating chamber. The treating chamber should have sufficient volume to allow the yarn to momentarily accumulate without excessive crowding upon an obstacle surface within the treating chamber prior to being withdrawn.

The following example illustrates operation of the apparatus in the process of this invention.

Example 1

A 1020 denier/68 filament yarn of polyhexamethylene adipamide is processed using a device similar to that shown in FIGURE 1. The yarn feed speed is 400 y.p.m. and the take-up speed is 222 y.p.m. to give an effective overfeed, based on feed speed, of 80%. The plasticizing fluid is steam at a temperature of 550 F. and a pressure of 85 p.s.i. Steam consumption at this rate of yarn processing is approximately 20 lbs./hr. The crimped yarn product is characterized by a random three-dimensional curvilinear crimp of the type described in copending application Serial No. 698,103, filed November 22, 1957, by Breen and Lauterbach, and is particularly useful as a rug or pile yarn. The amplitude, permanence, and number of crimps per unit of length in the filaments make the yarn particularly suitable for this purpose.

The claimed invention:

1. A process for imparting to a synthetic linear polymeric strand a dyeability rate at least 75% greater than that of the starting material, comprising continuously feeding the strand into a treating chamber in a direction passing across an obstacle surface within the chamber, jetting a plasticizing stream of compressible fluid having a temperature of at least 300° F. at high velocity into the chamber across said strand feed direction at an angle of at least 20° to change the direction of movement of the strand toward the obstacle surface, impinging the strand in a plastic state against the obstacle surface to provide an abrupt change in the latter direction of movement of the strand and adjacent fluid, conducting the strand and fluid from the chamber, the strand being removed at a rate less than the feed rate to provide an overfeed of at least 12%, quenching the strand while simultaneously expanding and reducing the velocity of the adjacent fluid, removing the strand from the fluid, and winding it on a package.

2. The process of claim 1 in which the fluid is steam.

3. The process of claim 2 in which the strand and steam after abruptly changing direction are passed concurrently through a strand quenching zone in which the steam is cooled by gradual expansion.

4. The process of claim 2 in which the steam is jetted against the polymeric strand at a velocity of at least ½ sonic velocity.

5. The process of claim 2 in which the strand is fed and removed at rates which provide an overfeed of at least 30% to the treating chamber.

6. Yarn treating apparatus comprising a housing forming the walls of a treating chamber, an obstacle surface within said chamber, yarn inlet means for feeding yarn into the chamber along an axis which is at a converging angle to said obstacle surface, fluid inlet means for jetting a compressible fluid into the chamber at high velocity along an axis crossing said axis of the yarn inlet means at an angle of at least 20° and directed against the obstacle surface, and tubular exit means for conducting both yarn and fluid from the chamber, said exit means having a reduced cross-sectional area relative to that of the chamber and an increasing cross-sectional area towards the exterior end to provide a controlled gradual expansion of fluid exiting from the chamber.

7. The apparatus of claim 6 in which the treating chamber has a volume between about 1 and about 10 times that of a sphere having a diameter equal to the sum of the diameters of the yarn and fluid inlet means at the point of interception of these inlet means with the treating chamber.

8. The apparatus of claim 7 in which the treating chamber is a frustum of a conical surface having an apex angle of between about 60° and about 120°.

9. The apparatus of claim 8 in which the apex angle is between about 80° and about 100° and the frustum has a height of not more than 1 times the diameter of the base.

10. The apparatus of claim 8 in which the axes of the yarn inlet means and fluid inlet means intersect within the chamber at a point spaced from the terminus of the fluid inlet means by a distance less than 15 times the diameter of the fluid inlet means at said terminus.

11. The apparatus of claim 10 in which the angle formed by the axes of the yarn and fluid inlet means is between about 25° and about 45°.

12. Yarn treating apparatus of claim 8 containing a deflecting member positioned within the chamber at the fluid inlet means terminus to direct incoming fluid toward the obstacle surface.

13. Yarn treating apparatus comprising a housing containing a treating chamber in the form of a frustum of a right conical surface having an apex angle of between about 80° and about 100°, a tubular exit from the chamber tapering divergently toward the exterior, the inner end of the tubular exit coinciding with the smaller base of the frustum; an entranceway for introducing yarn into the treating chamber and having a terminus in the larger base of the frustum and having a common axis with the conical surface and the tubular exit; an entranceway for introducing fluid into the treating chamber and having an inner terminus in the larger base of the frustum at a location in said base adjacent to the yarn entranceway, the axis of the entranceway for fluid forming an angle of between about 25° and about 45° with the axis of the yarn entranceway.

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