

July 29, 1969

J. R. WILLIAMS ET AL

3,457,610

TREATMENT OF FILAMENTS TO DEVELOP LATENT BULKINESS THEREIN

Filed Dec. 13, 1967

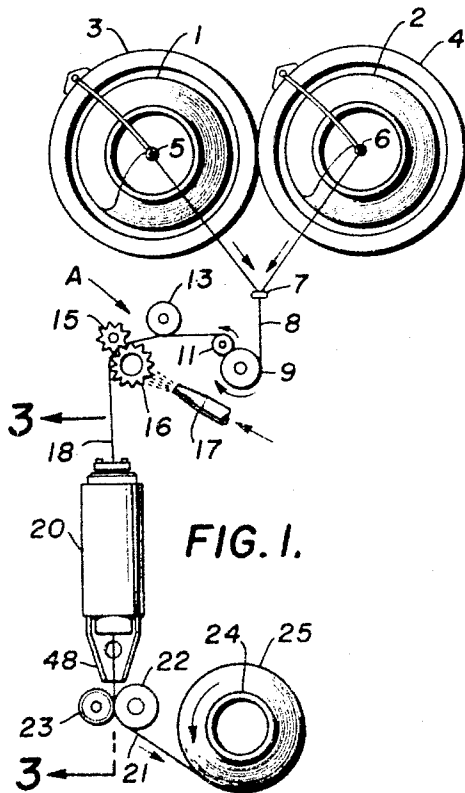


FIG. 1.

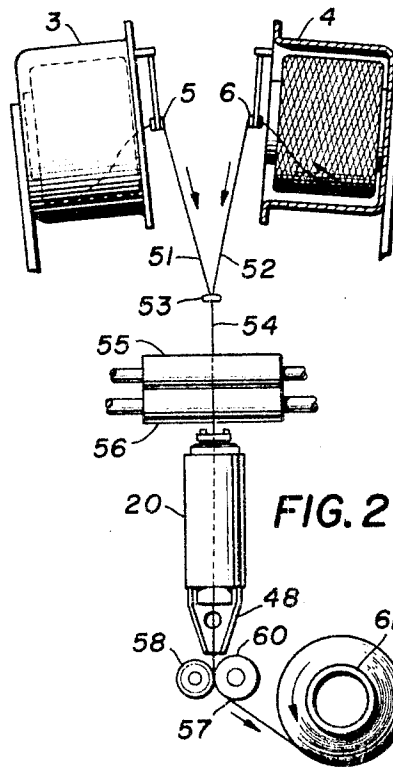


FIG. 2.

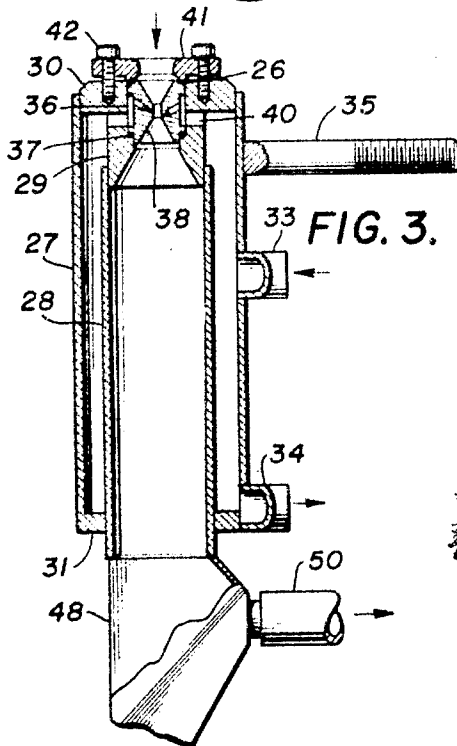


FIG. 3.

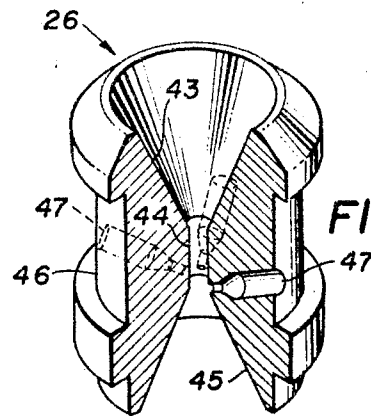


FIG. 4.

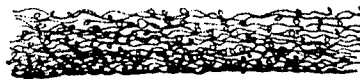


FIG. 5.

INVENTORS
EUELL K. MCINTOSH
JAMES R. WILLIAMS

BY

Stanley M. Tarter
ATTORNEY

1

3,457,610

TREATMENT OF FILAMENTS TO DEVELOP LATENT BULKINESS THEREIN

James R. Williams, Robertsdale, Ala., and Euell K. McIntosh, Pensacola, Fla., assignors to Monsanto Company, St. Louis, Mo., a corporation of Delaware

Filed Dec. 13, 1967, Ser. No. 690,281

Int. Cl. D02g 3/00; D02j 13/00; D04h 17/00

U.S. Cl. 28—1.4

7 Claims

ABSTRACT OF THE DISCLOSURE

The invention provides an apparatus and a method of treating synthetic thermoplastic continuous filament yarns having latent crimp or bulkiness such that the resultant yarns are better utilizable particularly in either conventional or high speed tufting machines, and yield excellent physical characteristics in the tufted fabric with minimal tufting operational defects. The method of the invention comprises passing one or more ends of yarns having latent bulkiness through a confined zone in which a high-velocity stream of heated fluid impinges upon the yarns to develop at least part of the latent bulkiness of the yarns and to mildly intertangle the filaments, thereby yielding a bulky but coherent tufting yarn.

BACKGROUND OF THE INVENTION

The invention concerns apparatus and a method of treating synthetic filamentary yarns having latent crimp or bulkiness that may be at least partially developed before the yarn is converted into a fabric in which the bulk may be subsequently more fully developed. Preferably, the practice of the invention provides multi-filament textured yarns having some residual latent crimp which is especially useful in the production of tufted fabrics for upholstery, carpets, and the like.

Many of the more widely used types of yarns have potential or latent crimp that is fully developed during the sizing or dyeing treatments applied to fabrics made therefrom. Prior to such fabric treating operations the yarn is more or less compact rather than bulky. Such potentially bulky yarns can be made by the hot-stretch gear-texturing process disclosed by Bromley et al. in U.S. 3,024,517. Potentially crimpable filaments can also be produced by conjugate spinning in which two different polymeric materials are eccentrically bonded together in single filaments, as exemplified by Breen in U.S. 2,931,091. Other methods, such as disclosed in British Patents 809,273 and 1,057,579, depend upon the unsymmetrical cooling of melt spun filaments which retain asymmetrical stresses that are relieved as crimps develop when the filaments are heated under conditions of low tension. Mechanical manipulation of the yarn is easier; and a more stable and desirable fabric structure is achieved if the potential crimp of the yarn is not fully developed until after the greige fabric has been made.

As the operating speed of tufting machines increased in commercial mills, it was found that completely unbulked textured yarns do not run without causing an intolerable number of tufting defects in the fabrics. One disclosed way of adapting the potentially crimpable yarns to the more severe tufting operation is to "prebulk" the yarn and apply a surface sizing material to the yarn prior to tufting. Such a process is exemplified by Hills et al. in U.S. 3,299,485. Recent changes in tufting machines have imposed even more stringent requirements upon the tufting performance of yarns which prior art yarns do not wholly satisfy. The conventional tufting needle with eye-

2

let has been replaced to a large extent by a hollow needle through which the yarn moves axially, partly driven by an air stream. This innovation permits the tufting speed or productivity of the machine to be greatly increased, provided the supply yarn is amenable to the newer operating conditions.

SUMMARY OF THE INVENTION

A method of treating man-made thermoplastic continuous filament yarn to develop the latent bulkiness thereof is provided. This is accomplished by passing untwisted or low twist drawn thermoplastic continuous filament yarn having a latent bulkiness through a confined zone with an overfeed of at least 15%. A plurality of small streams of heated fluid moving at a high velocity is directed against the yarn passing through the zone. The streams have inlets to the zone closely spaced apart in staggered relation with respect to the axis of the yarn and circumferentially arranged around the path of the yarn through the zone. The result is that the latent bulkiness in the yarn is developed and the filaments are entangled for improved tufting efficiency. The overfeed of the yarn is normally in the range of 15 to 60%. The fluid is preferably steam of 160° to 235° C. moving at a mass velocity of about 1.5 to 5.5 pounds per minute per square inch of cross section of the steam inlets.

Apparatus is also provided for developing latent bulkiness in continuous filament yarn and entangling filaments thereof. The apparatus includes a jet adapted to receive yarn for passage therethrough. Means are associated with the jet for supplying a heated fluid from a source. A plurality of conduits connect the fluid supplying means with the yarn receiving and discharging ends to direct a plurality of jetted streams of heated fluid onto the yarn. The conduits are closely spaced apart in staggered relation with respect to axial movement of the yarn and in circumferential arrangement around the path of the yarn.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a schematic representation of a preferred embodiment useful for practicing the invention.

FIGURE 2 is a schematic representation of apparatus suitable for carrying out another embodiment of the method of the invention.

FIGURE 3 represents an enlarged lateral section taken along line 3—3 in FIGURE 1 and shows internal structural features of one embodiment of apparatus of the invention.

FIGURE 4 is a quarter section in perspective of a jet nozzle according to the invention.

FIGURE 5 is a diagrammatic lateral view of a segment of multi-filament yarn treated according to the method and apparatus of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

The apparatus and process of the invention may be readily understood by reference to the drawing.

In FIGURE 1 there are shown two bobbins or supply packages 1 and 2 of undrawn thermoplastic continuous filament yarn stocked on a conventional creel frame within creel cans 3 and 4. The ends of yarn from each package pass separately through eyelets or pigtail guides 5 and 6 and together run through a pigtail guide or snubbing guide 7. The ends combined to form yarn 8 pass around driven feed roll 9 with its associated idler cot roll 11 and around heated pin or cylinder 13. From pin 13 the heated yarn passes through the nip of two intermeshing toothed drawrolls 15 and 16 that are driven at a peripheral speed several times greater than the speed of feed roll 9 so that heated yarn is given an orientation stretch while hot and is deformed and cooled as it passes between the denticulated rolls. The toothed drawroll can be positively cooled by a low velocity stream of air delivered through nozzle

17. Yarn issuing from the hot-stretch gear-crimp zone A now possesses a latent crimp or bulkiness that can be developed by heating the yarn under conditions of low tension as is well known.

The potentially crimpable yarn now referred to by reference numeral 18 passes axially through prebulker-tangler chamber 20, wherein a jet of heated high-velocity fluid directed against the moving yarn displaces the relative positions of the filaments and simultaneously heats the yarn to develop its latent bulkiness. The prebulked yarn now referred to by reference numeral 21 passes over a conventional driven delivery roll 22 with a nip-forming cot roll 23. From thence the yarn is wound up on bobbin 24 to form the finished package 25 of prebulked tangled yarn. Either surface driven bobbins, an over-end winder or other conventional windup system (not shown) can be used to package the yarn; or the yarn can be collected in a tow can with a conventional piddler assembly.

The structure and function of the prebulker-tangler 20 can be better understood by reference to FIGURE 3 which represents a longitudinal section along line 3—3 of FIGURE 2. The prebulker is comprised of a body assembly and a replaceable jet nozzle 26. The body has an outer shell 27 that can be cylindrical or have a square, rectangular or other cross section for convenience in fitting into existing equipment. Disposed coaxially with the axis of outer shell 27 is an inner cylinder 28 that is open at its lower end which projects beyond the end of the shell and is closed at its upper end by the cylindrical end piece 29 that is integral with upper end shell closure 30. The lower end of the shell is closed by end piece 31 that mates against the outside of inner cylinder 28. All junctions or contact surfaces between end closures and the shell and tube are welded or otherwise sealed to form strong leak-proof joints. In analogy with shell-and-tube heat exchangers, the open annular volume formed between the outer wall of the inner cylinder and the inner wall of the shell may be referred to as the "shell side," and the interior volume of the inner cylinder may be designated "tube side." Two nipples or half couplings 33 and 34 open into the shell side to provide an inlet and outlet, respectively, for a heated fluid. An externally threaded rod 35 welded to the shell provides convenient means for attaching the prebulker-tangler to a supporting bracket or to a machine frame.

Cylindrical opening 36 concentric with the axis of the inner cylinder is formed through the upper end closure 30. The diameter of the central opening is abruptly reduced about half way along the axis of the end closure to provide an annular shoulder 37 that supports jet nozzle 26. The central opening flares to form a diverging frusto-conical surface 38 into the tube side. A plurality of radial ports 40 pass through the wall of the end piece, forming passages for fluid from the shell side to the tube side. Removable jet nozzle 26 makes a snug fit into the end piece opening and bears against a sealing-ring gasket of soft metal, such as aluminum, supported by shoulder 37. A sealing-ring gasket of similar material is placed at the upper end of the nozzle, the two gaskets and nozzle being compressed into tight engagement by a follower ring or gland 41 held firmly in place by cap screws 42.

The structure of jet nozzle 26 is more clearly shown in the perspective view of FIGURE 4 which shows that the axial passage for receiving the yarn undergoing treatment is comprised of a converging frusto-conical inlet 43 that joins a short cylindrical bore 44 which at its lower end joins a diverging frusto-conical outlet section 45. Along a major portion of the length of the nozzle its outside diameter is reduced to provide a circumferential channel 46 that registers with radial ports 40 of the body assembly shown in FIGURE 3. The outer edge of the upper end of the nozzle forms an external conical surface to aid in the centering and sealing of the upper ring gasket.

A plurality of conduits 47 spaced apart along the axis of the jet and spaced circumferentially about the axis,

connect circumferential channel 46 with the inner bore 44. As indicated, for ease of fabrication, the conduits may have an enlarged entrance counterbore which converges to the small exit the small orifice through the wall of the central bore. The axes of the conduits 47 may be normal to the axis of the central bore of the jet but preferably are angled such that an appreciable component of the fluid velocity is directed along the axis of the central bore. If the direction of movement of the yarn is taken as the positive direction of the central axis of the bore, then the axes of the conduits are preferably at an obtuse angle of 10–175° with respect to the central axis of the bore. The actual diameter of the central bore depends, of course, upon the size of the yarn or tow being treated. In general, the bore diameter should be in the range of 2 to 10 times the nominal diameter of the yarn being treated; when the bore is excessively large there is a sporadic tendency to develop twist in the composite filament bundle and to develop undesirable crunodal loops in the individual filaments; a small degree of taper in the central bore can also be desirable. Similarly, the diameter of the exit orifices of the conduits should be in the range of one-tenth to one-half the diameter of the central bore. Usually it is desirable, especially with large threadlines or tows, to have at least one of the fluid conduits open into the central bore just upstream of the diverging outlet.

The cone angles or angles of convergence and divergence of the frusto-conical inlet and outlet sections, respectively, of the jet nozzle can be equal; for large threadlines or tows, however, the inlet convergence angle and the outlet divergence angle can be unequal. To avoid undesirable turbulence, the divergence angle of the outlet section is made equal to or less than the divergence angle of the upper end closure of the prebulker body (surface 38, in FIGURE 3). The cone angles for both converging and diverging sections should be within the range of about 15°–95°.

As indicated by numeral 48 in FIGURES 1–3, a metal duct having an open front is mounted directly below the prebulker-tangler. Suction line 50 (FIGURE 3) is connected to the duct so that volatile components or moisture escaping from the outlet of the prebulker-tangler are drawn away from the operating area. The suction or vacuum source connected to line 50 can be the inlet side of a common air blower with a condenser and condensate trap upstream of the blower. A water-actuated aspirator or a low efficiency steam-jet squelched with water are very useful suction sources, particularly when steam is the active fluid in the prebulker-tangler. The principal flow of fumes is normally downward from the operating prebulker-tangler because of the fluid drag of the moving threadline.

A second preferred embodiment of the invention is represented schematically in FIGURE 2 and is readily understood by comparison with FIGURE 1. In this embodiment a plurality of yarns already having latent crimp or bulkiness are treated by the method of the invention to yield a single bulky coherent threadline. From bobbins stocked in conventional creel cans yarns 51 and 52 are led out through centering guides and are brought together at thread guide 53. The resultant threadline 54 passes into the nip of feed rolls 55 and 56 which forward the threadline into prebulker-tangler 20 wherein the yarn filaments are laterally displaced with respect to one another and are heated by high velocity streams of hot fluid to partially develop the latent crimp of the filaments. The resultant coherent bulky threadline 57 passes through the pinch of the delivery roll combination 58 and 60 and is wound onto bobbin 61 by a conventional winder or coner.

The operational embodiment of the invention illustrated in FIGURE 2 is particularly useful whenever it is commercially feasible to maintain an inventory of yarn having potential crimp. A wide range of sizes of prebulked coherent yarns may be produced as required by market conditions simply by combining the appropriate number

of single ends of the potentially bulkable yarn. It is quite practicable and economically feasible to produce treated yarns of sizes ranging from a few hundred denier of a single end to many thousands of denier of a plurality of combined ends, the jet nozzle (FIGURE 3) being replaced as necessary by one of appropriate size.

Instead of supplying the undrawn thermoplastic yarn from bobbins 1 and 2, it is obvious that the yarn can be taken directly from the spinning heads of a conventional spinning machine, thus constituting a direct continuous process for production of the coherent bulky yarn end product. A number of handling steps are eliminated in this continuous process.

On a large enlarged scale, FIGURE 5 represents the general appearance of coherent bulky yarn produced according to the method of the invention and held under slight tension. The filaments of the threadline cohere together due to the moderate degree of lateral interlacing of the filaments comprising the yarn. Under moderate tension, such as occurs in normal tufting or weaving operations, the bulky yarn contracts in diameter by 100-200% and assumes a compact smooth appearance but recovers its bulkiness and retains its coherence when the tension load is removed. When appreciable tension is applied sufficient to strain the yarn beyond the nominal elastic limit corresponding to complete straightening out of the crimps, the yarn recovers its bulkiness but loses its coherence when the tension is released. If two or more yarns are plied together, they tend to separate after appreciable tension has been applied and released. These observations provide a simple practical test for checking the operation of the prebulking-intertangling process. An experienced operator simply applies moderate tension by hand to a length of the treated yarn and releases it. If the filaments fail to cohere, insufficient interlacing is occurring. Thereupon, corrections are made accordingly in the operating conditions. Similarly, if the filaments tend to cohere after appreciable tension is applied to the yarn and is released, excessive intertangling occurred. Thereupon, process conditions are accordingly adjusted. The degree of interlacing is strongly dependent upon the relative linear rates of yarn into and out of the prebulker-tangler as well as upon the rate of flow of fluid through the jet nozzle; these matters are discussed subsequently.

It is to be noted, as indicated in FIGURE 5, that yarn treated according to the method of the invention contains only a few crunodal or closed loops in the filaments. Many of the apparent crunodal loops in filaments shown in FIGURE 5 are simply due to projection and are not actual loops. The development of sizeable crunodal loops in the yarn is to be avoided because of at least two adverse effects. Except for tiny crunodal loops, such loops occur only under operating conditions that lead to excessive coherence among the filaments, as indicated by the hand-tensioning check mentioned above. Not only does the presence of loops on the outer surface of the yarn seriously hinder the passage of the yarn through the tufting needles, the appearance of the finished tufted fabric is also adversely affected. In the scouring and dyeing treatment of the fabric the residual bulk in the yarn is fully developed so that desirably the tufts tend to pull down slightly and to expand or "bloom." With excessively coherent yarn the more restrained interior filaments do not fully develop their potential crimp and the tufts tend to appear skimpy or lean while the exposed surface loops do bulk, giving a somewhat fuzzy appearance to the tuft that impairs tuft definition and pattern definition of fabrics, two of the more important aesthetic qualities determining the commercial acceptance of a particular tufted fabric. A highly important characteristic of yarns treated according to the invention is that they provide outstandingly superior tuft definition and pattern definition in the finished tufted fabric, especially in scroll pattern designs.

It is noteworthy that filament action occurring in the process of the invention differs appreciably from that in the usual processes in which yarn with potential crimp

is heated under low tension without the entangling action of a high velocity fluid stream or in which yarn not having potential crimp is subjected to a high velocity fluid stream to develop bulk by the formation and entanglement of filament loops. In the jet nozzle according to the invention, the filaments under low tension are simultaneously heated and displaced by the fluid stream so that the developing potential crimps tend to provide significant three-dimensional interlocking of the displaced filaments without the formation of large filament loops. Subjection of the "intercrimped" filaments to extended heating immediately beyond the jet nozzle tends to set the filaments in the intertangled configurations.

In the operation of the prebulker-tangler optimal conditions for a given type of synthetic yarn are normally determined empirically, since the aesthetic qualities desired in a given tufted fabric are not accurately predictable from yarn properties; minor adjustments in the initial process are usually necessary to provide the ultimately desired qualitative characteristics. Suitable initial conditions may be chosen by considering the more important process conditions.

Many different fluids may be used to heat and intertangle filaments of the potentially crimpable yarn, such as steam, heated air, nitrogen, etc. Air and steam are the more economical, steam being preferred for treating filaments of nylons or polyesters. The high velocity fluid through the conduits of the jet nozzle provides both heat to the filaments and kinetic energy to displace the filaments laterally. The desired degree of yarn coherence is normally obtained when the linear velocity of the fluid is less than sonic velocity in the fluid at the operating temperature and pressure. However, the term "velocity" is somewhat ambiguous in this context; and "mass velocity" is a more appropriate measure of flow rate. According to the invention, the mass velocity of fluid through each orifice of the conduits is in the range of 1.5 to 5.5 pounds of fluid per second per square inch of orifice cross section (lb./sec. in.²). The required fluid flow rate also depends upon the size of the yarn and the linear speed of the yarn undergoing treatment. For the commercially significant nylon and polyester filament yarns a mass flow rate of about 2.75 to 4.25 lb./sec. in.² is suitable.

The temperature to which the yarn must be heated by the streams of fluid depends upon the material comprising the yarn. In general, the yarn must not be heated above the sticking temperature of the material comprising the filaments. Otherwise, the filaments tend to fuse together at the surface, forming a stiff boardy yarn difficult to convert into fabric. The actual temperature of the fluid itself can exceed the softening point of the material and may of necessity do so at very high yarn speeds in order to heat the yarn sufficiently during its short exposure to the fluid. Temperatures below about 135° C. are too low to sufficiently heat the threadline moving at appreciable speeds. For nylons and polyester filaments, operating fluid temperatures within the range of 165°-230° C. have proven quite satisfactory with somewhat higher temperatures being useful for large yarns or tows, provided the filaments do not soften and inordinately stick together. Auxiliary heaters may be useful when preheated superheated gases, such as air, are employed. In the chains hereinbelow with reference to the preferred fluid steam, the temperature cited is the temperature of the saturated steam on the shell side upstream of the jet nozzle conduit orifices. It is to be understood that the actual temperature of the steam in the free jet immediately downstream of the orifices can be a few degrees higher than the saturation temperature because of semi-adiabatic expansion of the steam passing through the conduits. Experience has shown, however, that this degree of superheating does not justify a correction being applied in the specifying of the temperature.

The principal controllable factor determining the bulkiness of a given yarn treated under otherwise constant

conditions is the extent of overfeed of the yarn into the prebulker-tangler unit. Overfeed expressed as a per centum is the excess linear rate of yarn entering the prebulker compared with the linear rate of the yarn leaving the prebulker, and is controlled by the relative speeds of the yarn delivery rolls immediately upstream and downstream of the prebulker-tangler. For example, if the delivery rolls 55-56 and 58-60 in FIGURE 2 are running at such speeds that yarn passes into the prebulker-tangler at a rate of 150 yds./min. and is removed from the prebulker-tangler at a rate of 100 yds./min., the overfeed is 50%. In general, the lower the overfeed the lower will be the bulk of the treated yarn. The overfeed cannot be increased indefinitely, however, without changing the nature of the prebulking-tangling operation; i.e., the potential crimp development plus the moderate displacement of the filament may not compensate for the high degree of overfeed so that undesirable large crunodal loops form in the filaments. To provide the prebulked-tangled yarns having the previously-mentioned desirable characteristics, according to the invention the percent overfeed must not exceed numerically by more than about 30 units the potential crimp as measured by the dry bulk determination outlined below. That is,

$$\text{Maximum percent overfeed} = [\text{percent dry bulk} + 30]$$

Superficially, it might appear that the overfeed could not exceed the potential crimp at all without developing the undesired crunodal loops. However, it must be noted that a certain degree of shrinkage occurs in the heat treatment of yarns whether or not the yarn is made potentially crimpable prior to treatment; such shrinkage may be as much as 8-12%, depending upon the particular previous treatments the yarn has received in the course of its manufacture; an appreciable longitudinal shortening of the yarn also occurs as the filaments are made to deviate from their ordered paths by the restrained intertanglement due to the turbulent fluid stream.

It is now common practice to describe the degree of bulk or crimp of a yarn by the change in length of the yarn under some specified condition of loading after the yarn has been heated under no tension to fully develop its crimp or bulk. "Dry bulk," as referred to in the preceding paragraph and in the examples to follow, is determined by an arbitrary procedure which provides reproducible data: 2.5-4.0 grams of yarn are wound into a skein the loop length of which is about 40-50 centimeters; the actual length of yarn in the skein varies with the denier or size of the yarn but is usually within the range of 6-50 meters.

The yarn skein looped over a steel supporting rod is suspended in a laboratory oven for exactly 5 minutes, the oven being controlled at a temperature of $121 \pm 2^\circ$ C. The heated skein is next removed from the oven and looped over a fixed hook, and a hook bearing a 50 gram weight is hooked through the free end of the skein loop to provide tension in the skein; exactly 30 seconds later the length of the loop is measured with a vertical scale. Then an additional weight of 4.54 kilograms is added to the 50 gram weight, and 30 seconds later the length of the stretched loop is again measured. The difference in the respective measured loop lengths expressed as per centum of the loop length under the 50 gram load is designated the "percent dry bulk." As an example, after heating, the measured length of a skein under 50 grams loading is 40.0 centimeters, and under 50 grams plus 4.54 kilograms loading the length is 50.0 centimeters; the dry bulk of this sample would be 25%.

Another useful measurement of bulk is termed "wet bulk." The procedure for its determination is identical with that for dry bulk except in the heating of the yarn skein. The skein is suspended under no tension in boiling water for 10 minutes and immediately following is heated in a laboratory oven at $121 \pm 2^\circ$ C. for 30 minutes before

the skein length is measured as in the method for dry bulk. The percent wet bulk usually exceeds the percent dry bulk of a given yarn by a few percent and is reasonably invariable with time. That is, if for a given specimen of yarn the dry bulk and the wet bulk are measured, the percent wet bulk will numerically exceed the percent dry bulk by a small quantity; and if the wet bulk and dry bulk of samples of the same specimen are redetermined after a lapse of time, say a few months, the percent wet bulk will have changed very little but the percent dry bulk will have decreased appreciably compared with the initially measured values. The percent wet bulk is therefore a more suitable characterization factor for the final yarn product, but the percent dry bulk is very convenient and useful for checking the operating conditions and controlling the prebulking-intertangling process. The percent wet bulk also indicates the degree of drawing down of tufts in the tufted fabric, since the dyeing and finishing of these fabrics involve extended exposure to hot aqueous solutions followed by drying.

Illustrative examples of the practice of the invention follow.

A prebulker-tangler body assembly was made up substantially as indicated in FIGURE 3 with the outer shell comprised of standard $2\frac{1}{2}$ inch pipe and the inner cylinder of standard $1\frac{1}{2}$ inch pipe that projected $\frac{1}{2}$ inch beyond the lower end of the shell. The upper end piece integral with inner cylinder end closure was bored to a diameter of $\frac{3}{4}$ inch with shoulder spaced 1 inch from the top end; the portion of this bore below the shoulder diverged at 60° cone angle. Two radial holes $\frac{3}{16}$ inch in diameter formed the ports connecting shell and tube side. Two $\frac{1}{4}$ inch pipe couplings opened into the shell. Follower ring was made with a control opening $\frac{1}{2}$ inch in diameter; four cap screws were provided to lock the follower ring in place.

A jet nozzle was made substantially as illustrated in FIGURES 3 and 4. The overall outside diameter was $\frac{3}{4}$ inch and overall length was 1 inch. The converging inlet had a cone angle of 60° and the central cylindrical bore was $\frac{5}{64}$ inch in diameter by $\frac{7}{32}$ inch long, and joined the diverging outlet having a 60° cone angle. A single conduit was drilled through the wall of the bore normal to the axis of the bore; the counterbore portion of the conduit was $\frac{3}{32}$ inch in diameter and the diameter of the orifice opening into the bore was 0.025 inch. This jet nozzle was locked into the body assembly by means of the follower ring and two aluminum ring gaskets as shown in FIGURE 3.

The prebulker-tangler was mounted 12 inches below a driven feed roll-cot roll combination on a vertical frame surmounted by a creel as indicated in FIGURE 2. A similar roll combination was located about 10 inches below the prebulker-tangler and a standard Model 959 winder manufactured by the Leeson Corp. was located below the lower driven rolls. The upper coupling of the prebulker-tangler shell was connected to a steam header by means of pipe with a pressure gage and steam pressure regulator immediately upstream. The lower coupling was connected to an ordinary Sarco steam trap that drained to the sewer. The prebulker-tangler was thermally insulated with standard-thickness magnesia pipe covering and wrapped with seamed asbestos cloth. The follower ring was left uninsulated and exposed so that the jet nozzle could be easily removed and replaced. A funnel-mouthed aluminum duct immediately below the prebulker-tangler was connected to a vacuum source to draw away fumes from the operating area.

EXAMPLE I

With the apparatus as described above, a single bobbin of gear-textured nylon 66 yarn having potential crimp was stocked on the creel. This yarn having nominal denier of 1230 and 68 filaments was brought through guides over the top feed roll, through the prebulker-tangler, over the bottom delivery roll and to the windup bobbin as indi-

cated in FIGURE 2. Speeds were set to feed yarn into the prebulker-tangler at 200 yards per minute (y.p.m.) and to remove it at 150 y.p.m. or the equivalent of 33% overfeed. Steam was admitted to the shell side of the prebulker-tangler at low pressure which was increased periodically, and samples of the treated yarn were examined visually. It was evident that significant discernible prebulking of the yarn did not occur unless steam pressure was at least 50 lb./sq. in. guage (p.s.i.g.), which corresponds to a saturation temperature of 148° C. Steam pressure was successively increased until prebulking of the yarn was regarded as satisfactory, but under none of the conditions was uniform intertangling of the filaments observed. The jet nozzle was removed and an additional conduit orifice of identical size was drilled diametrically opposite the first orifice. The jet nozzle was reinstalled in the body assembly and another series of operational trials were made. Prebulking of the yarn was improved for lower pressure steam but uniformity of intertangling was not appreciably improved: Excessively large and dense interlacing occurred sporadically, the intervening several inches of yarn being rather loose, and individual filaments being erratically separated.

A new jet nozzle was made with dimensions identical with the first-mentioned but the two orifices were displaced one from the other along the axis of the central bore by a distance of $\frac{1}{16}$ inch. Under test conditions this nozzle provided a significant improvement in tangle uniformity without sacrifice in prebulking development. Further testing indicated that satisfactorily prebulked and intertangled yarn could be produced; however, the range of suitable yarn speeds and rates of overfeed was somewhat restricted. Another conduit orifice was added, this orifice being displaced along the axis of the bore such that the orifice opened through the wall just at the position where the diverging conical outlet joined the lower end of the central bore. The axis of the third conduit was disposed circumferentially 90° from the axes of the other two conduits, and in a vertical plane this conduit made an angle of 120° with the axis of the central bore, the downward or direction of yarn movement being taken as the positive direction of the bore axis. With this orifice in place in the body assembly, further tests were made. Satisfactory prebulking and entanglement of the filaments were achieved over a wider range of yarn speed and overfeed, the component of fluid drag due to the angled third conduit helping to stabilize movement of the yarn into the prebulker-tangler.

Another jet nozzle was made with overall dimensions as before but modified to incorporate the essential and desirable features demonstrated in the prior tests. The appearance and form of this jet was similar in form to the one illustrated in FIGURE 4. However, to make the nozzle more versatile in treating yarns of widely differing sizes, the lower portion of the central bore itself was made slightly diverging in the direction of yarn movement. The converging frustoconical inlet to the nozzle had a cone angle of 60° and extended a distance of $\frac{3}{8}$ inch along the central axis. The entrance of the central bore $\frac{3}{64}$ inch in diameter extended along the axis $\frac{3}{32}$ inch and merged with a diverging frustoconical portion having a 15° cone angle; this diverging portion of the bore continued $\frac{5}{16}$ inch along the central axis and joined the diverging frustoconical outlet having a 60° cone angle. Three conduits with $\frac{3}{32}$ inch inlet counterbore and an orifice diameter of 0.025 inch were drilled through the wall of the nozzle. The three orifices were spaced along the axis of the central bore $\frac{5}{64}$ in. apart, the center of the first orifice being located $\frac{1}{16}$ inch below the junction of the straight and diverging sections of the central bore. Circumferentially, the three conduits were equispaced 120° apart, and in a vertical plane the axis of each conduit was at an angle of 130° with respect to the axis of the central bore. This kind of jet nozzle was used in the prebulker-tangler employed in the tests described in Examples II, III, and IV.

EXAMPLE II

With the prebulker-tangler mounted as described in Example I and as shown in FIGURE 2, a sample of continuous filament carpet yarn for light weight carpets was made. A single bobbin of supply yarn was mounted on the creel and the single end of yarn was threaded through the apparatus as indicated in FIGURE 2. The supply yarn was comprised of semidull nylon 66 having a total denier of 2460 and 136 filaments, gear-textured potential crimp, and $\frac{1}{2}$ turn per inch of S twist applied to the yarn bundle. The dry bulk of this yarn was 30%. The prebulking-tangling operation was performed under these conditions:

Upper feed roll speed	-----y.p.m.	350
Lower delivery roll speed	-----y.p.m.	250
Overfeed	-----percent	40
Steam pressure (shell side)	-----p.s.i.g.	265
Steam temperature (saturated)	-----° C	211

The tension control on the Leesona 959 winder was set to control at 100 grams tension in the yarn as it was wound on a cardboard tube. The process operated very smoothly, and a large number of small bobbins of the treated yarn was collected. The threadline was very uniformly coherent and bulky under no tension. By the hand tensioning test the yarn was observed to cohere together well after application of moderate tension and the filaments separated after application of appreciable tension. Examined at low magnification (about 4×) by projection with a microfilm reader, the threadline was seen to have an appearance similar to the illustration in FIGURE 5, the more nearly sinusoidal crimps in the feed yarn having been distorted somewhat and displaced to interlock in many directions about the axis of the threadline; only a few very tiny crunodal loops were discernible, the larger undesirable loops being entirely absent. The average wet bulk of the treated yarn was 28%.

A conventional needle-and-hook tufting machine at $\frac{3}{32}$ inch gauge was used to prepare sample carpets 28 in. wide of 16 oz./sq. yd. and 20 oz./sq. yd. weight with standard plain weave jute for backing material. Two types of carpet construction were used at each weight, one a level loop pile with $\frac{1}{16}$ inch pile height and the other a high-low pattern with pile heights of $\frac{1}{2}$ inch and $\frac{1}{8}$ inch. For comparison, similar fabrics were tufted with a commercial carpet yarn of the same size that is made of the same type of supply yarn but is prebulked and with a special sizing material applied.

In the tufting operation the test yarn performed significantly better than the comparison commercial yarn: there were many fewer back picks or pulled out loops and virtually no stray or broken filaments were discernible.

Portions of each sample fabric were piece-dyed a deep green shade by standard procedures. Five technically qualified fabric inspectors examined the fabrics in both the greige and the dyed form. It was their unanimous opinion that the test fabric was distinctly superior by all common criteria, particularly in the patterned fabric: the pattern and tuft definition was outstanding and the resilience and plush feeling of the sample carpet was much more aesthetically appealing.

EXAMPLE III

Samples of prebulked-tangled carpet yarn were prepared under the same operating conditions outlined in Example II except that the supply yarn was changed. Three bobbins of nylon 66 yarn having gear-textured potential crimp were stocked on the creel. Each end of yarn comprised 68 filaments having 1230 total denier and about $\frac{1}{4}$ turn per inch of Z twist. The three ends of yarn were brought together with appropriate guides and passed through the prebulker-tangler to the winder as previously described. The nominal dry bulk of the supply yarn was 27-32%. The resultant product yarn was comprised of 204 filaments with total nominal denier of 3690 and zero ply twist.

The prebulked-tangled yarn possessed the previously observed uniform coherence and bulkiness with absence of loops; the average wet bulk of the yarn was 26%. A large number of moderate size packages of yarn were collected and were transferred to a commercial carpet mill for testing.

On a conventional commercial tufting machine of $\frac{5}{32}$ inch gauge the test yarn was included to make a 30 inch wide swath of tufted fabric at 23 oz./sq. yd. weight in 10 oz. jute backing. Two different patterns were used: a high-low loop and a high-medium-low loop design; in the high-low pattern the high pile was sheared. An adjacent swath 30 in. wide of comparable commercial yarn that was prebulked and sized was included in addition to a third 30 inch swath made of another type of bulky nylon 66 commercial carpet yarn; the entire fabric was 90 inches wide. On the commercial tufting machine, the test yarn showed excellent performance.

The comparison fabric was dyed a gold shade and was backsided, laminated with secondary backing, and finished by standard commercial methods. The carpet panel of test yarn was judged to be at least equal to the commercial yarn panels in every respect and was distinctly superior in tuft and pattern definition, resilience, and "plushness," an important but vaguely defined aesthetic quality desired in carpets.

Samples of the test yarn and the commercial carpet yarns were next compared on a new high-speed commercial tufting machine which utilizes hollow needles and air-driven yarn to form loops instead of the conventional looper needles and hooks. Mill personnel successively increased the tufting speed. As speed increased beyond the maximum attainable with conventional tufters, the prebulked-sized commercial yarn caused so many defects it had to be removed from the machine; at still higher speed, the second commercial yarn also failed and had to be removed. The prebulked-tangled test yarn continued to perform well with minimal defects as tufting speed was increased to the maximum attainable with the pulley combinations available at the mill. Personnel at the commercial mill believed that the test yarn would have continued to perform satisfactorily at even higher speeds had pulleys been available to operate at the still higher tufting speeds. It was evident that the test yarn not only had desirable characteristics in finished carpets, but was capable of being tufted at speeds well above those used in conventional carpet production.

EXAMPLE IV

Apparatus as illustrated in FIGURE 1 was mounted on the face of a vertical frame surmounted by a yarn creel. The upper feed roll 9 and lower delivery roll 22 were of equal diameter and the mating cot rolls 11 and 23 were covered with dense polyurethane elastomer to insure good contact. The heated drawpin 13 was 2 inches in diameter and was heated with a 1000 watt cartridge heater. The prebulker-tangler assembly mounted between the draw-texturing gears and the lower delivery rolls was identical with the one previously described in Examples II and III.

Two bobbins of undrawn semidull nylon 66 yarn, each of 3900 denier and 68 filaments, were mounted on the creel; the two ends of the yarns were brought together at the upper roll guide 7 and were carried through the apparatus as indicated in FIGURE 1, the treated yarn being wound up on cardboard tubes by the Leeson 959 winder. The combined yarns made three wraps around the heated drawpin and made three passes through the nip of the draw gears, a conventional auxiliary separator roll being used to prevent the yarn wraps from overlapping. The process was operated under these conditions:

Upper feed roll speed	-----y.p.m.---	125
Draw-gear speed	-----y.p.m.---	401
Draw ratio	-----	3.20
Lower delivery roll speed	-----y.p.m.---	330

Overfeed	-----percent---	21
Drawpin temperature	-----° C---	200
Cooling air on gears	-----cu. ft./min---	15
Steam pressure (shell side)	-----p.s.i.g---	260
Steam temperature (saturated)	-----° C---	208

Prior to passage through the prebulker-tangler, the textured yarn had a dry bulk of 21%. The prebulked-tangled yarn had a denier of 2590 and a wet bulk of 24.7%.

Tufted carpets in two different high-low tuft patterns and one level-loop construction were made on a $\frac{5}{32}$ in. gauge conventional tufter using samples of the test yarn and a similar commercial yarn that had been prebulked and sized. Sample fabrics were made up in three different weights, 16 oz., 20 oz., and 25 oz. per sq. yd. with standard jute backing material. All samples were commercially finished and piece-dyed to a green shade.

Tufting performance of the test yarn was outstandingly good with minimal back pulls, loops, and other defects. Judged by five competent observers, the carpet fabrics of test yarn were judged to be superior in all respects, especially in aesthetic appeal, particularly in the patterned fabrics, in which the pattern and tuft definition were impressively superior.

EXAMPLE V

The procedure of Example IV was followed except the two ends of nylon 66 yarns had different additives incorporated in the polymer to render a considerable difference with respect to their receptivity to acid dyes. When tufted into fabric and dyed with an acid dye, the composite yarn provided a pleasing heather effect free of objectionable streaks. The additives incorporated in one end to enhance the acid dyeability thereof are disclosed in U.S. Patent 3,310,534. The additives incorporated in the other end to render the same resistant to acid dyes are disclosed in application Ser. No. 553,715, filed May 31, 1966 (now U.S. 3,375,651).

From the foregoing it is seen that the advantages of the present invention are many. The method results in developing at least part of latent bulkiness in synthetic thermoplastic continuous filament yarn and in intertangling to a mild degree of the filaments composing the yarn. The resultant yarn is bulky and has the coherency to be utilized in high speed tufting machines with excellent mill efficiency. The apparatus is of rather simple construction. It can be incorporated in existing machinery without extensive modification thereof. Other advantages are obvious.

Many different embodiments of the invention may be made without departing from the spirit and scope thereof.

We claim:

1. A method of treating man-made thermoplastic continuous filament yarn to develop the latent bulkiness thereof comprising:

(a) longitudinally forwarding untwisted or low twist drawn thermoplastic continuous filament yarn having latent bulkiness;

(b) passing said yarn through a confined zone with an overfeed of at least 15%;

(c) directing a plurality of small streams of heated fluid at 160° to 235° C. moving at a mass velocity of about 1.5 to 5.5 pounds per minute per square inch of cross section of the fluid inlets against the yarn passing through the zone, said streams having inlets to the zone closely spaced apart in staggered relation with respect to the axis of the yarn and circumferentially arranged around the path of the yarn through the zone, whereby the latent bulkiness in the yarn is developed and the filaments are entangled for improved tufting efficiency; and

(d) collecting the yarn in a uniform manner.

2. The method of claim 1 wherein the overfeed of the yarn is in the range of 15 to 60%, the fluid is steam

13

and the inlets are in substantially symmetrical circumferential arrangement.

3. The method of claim 2 wherein the yarn is made from a nylon polymer.

4. The method of claim 2 wherein the yarn is made from a polymeric fiber-forming ester. 5

5. A method of treating man-made thermoplastic continuous filament yarn comprising:

(a) forwarding at least two ends of substantially untwisted undrawn thermoplastic continuous filament yarn longitudinally from separate sources of supply; 10

(b) combining the plurality of ends and drawing the resulting threadline at an elevated temperature to increase the molecular orientation thereof;

(c) simultaneously deforming and cooling the drawn threadline by passing same between cool toothed meshing gear members;

(d) immediately thereafter passing the threadline through a single confined zone with an overfeed of at least 15%; 20

(e) directing a plurality of small streams of steam at 160° to 235° C. moving at a mass velocity of about 1.5 to 5.5 pounds per minute per square inch of cross section of the fluid inlets against the threadline passing through the zone, said streams having inlets to the zone closely spaced apart in staggered relation with respect to the axis of the yarn and circumferentially arranged around the path of the yarn through the zone, whereby the latent bulkiness in the yarn is developed and the filaments are entangled for improved tufting efficiency; and 25

(f) collecting the yarn in package form. 30

6. Apparatus for developing latent bulkiness in continuous filament yarn and entangling the filaments thereof comprising: 35

(a) a jet adapted to receive yarn into one end thereof and to discharge yarn from the other end thereof;

14

(b) means associated with said jet for supplying a heated fluid from a source;

(c) a nozzle inserted in said jet;

(d) said nozzle having two frusto-conical bores interconnected at their smaller ends by a cylindrical bore defining an axial yarn path therethrough;

(e) a plurality of conduits connecting said fluid supply means with the cylindrical bore to direct a plurality of jetted streams of heated fluid onto the yarn;

(f) said conduits being closely spaced apart in staggered relation with respect to the axial movement of the yarn and in circumferential arrangement around the path of the yarn.

7. The apparatus of claim 6 wherein the axis of each of the conduits forms an obtuse angle with the movement of the yarn downstream of the fluid discharge points of the conduits and wherein the conduit discharge points are in substantial symmetrical circumferential arrangement.

References Cited

UNITED STATES PATENTS

3,110,151	11/1963	Bunting et al.
3,259,952	7/1966	Caines.
3,262,179	7/1966	Sparling.
3,296,785	1/1967	Hardy.
3,299,485	1/1967	Hills et al.
3,325,872	6/1967	Ethridge et al.
3,372,446	3/1968	Schichman et al.

FOREIGN PATENTS

658,465	5/1965	Belgium.
1,064,765	4/1967	Great Britain.

JAMES KEE CHI, Primary Examiner

U.S. Cl. X.R.

28—1.3, 1.8, 62, 72.11, 72.12, 72.15; 57—34