July 29, 1969 S. R. NECHVATAL ET AL 3,457,611

APPARATUS FOR CRIMPING THERMOPLASTIC YARNS

Filed Oct. 10, 1967

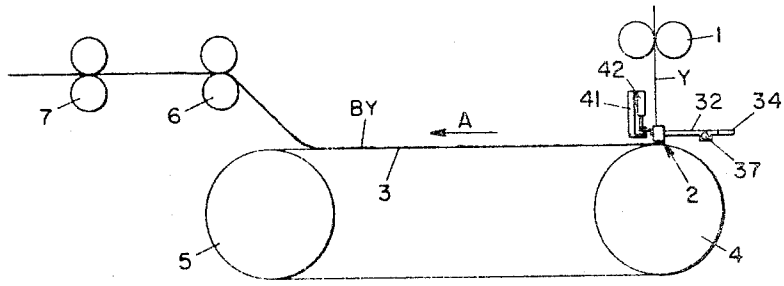


FIG. 1

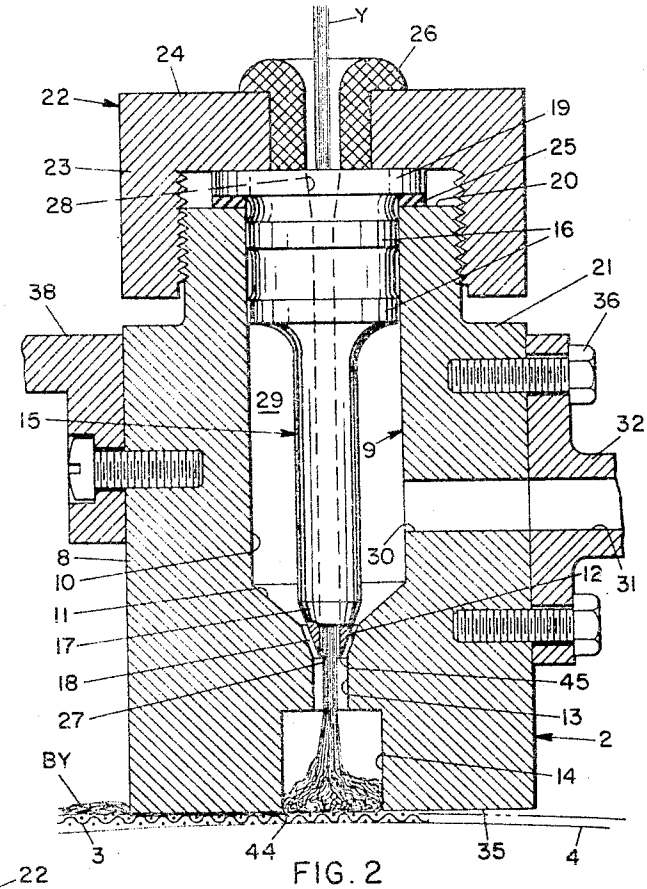
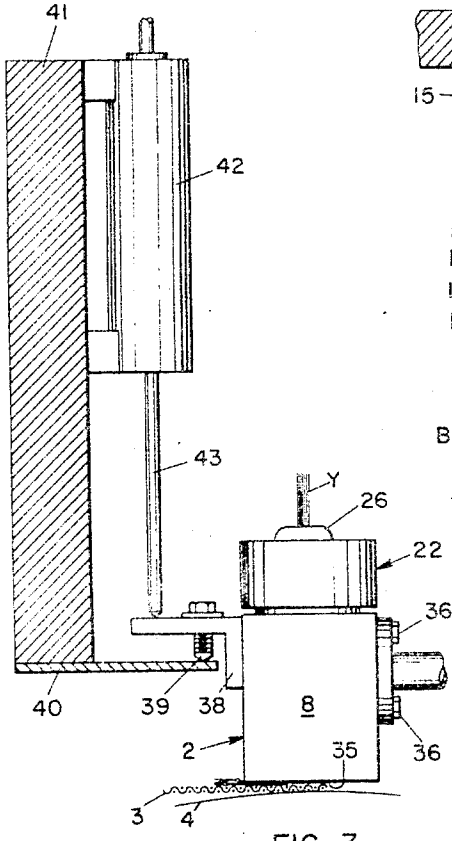


FIG. 2



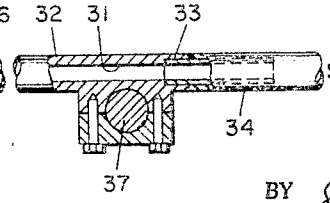


FIG. 3

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United States Patent Office 3,457,611 Patented July 29, 1969

3,457,611

APPARATUS FOR CRIMPING THERMOPLASTIC YARNS

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Filed Oct. 10, 1967, Ser. No. 674,279
Int. Cl. D02g 3/00; D04h 17/00; D05c 15/00
U.S. Cl. 28—1 16 Claims

ABSTRACT OF THE DISCLOSURE

The present invention relates to apparatus and process for crimping thermoplastic yarn and is characterized by a fluid jet unit having a bulking chamber, the exit of which is disposed immediately adjacent to a screen means. The jet unit is yieldably mounted for movement away from the screen and biased into its operative position relative to the screen. The bulked yarn issues on the screen from beneath the jet unit as a smooth ribbon of yarn that is essentially free from loose loops, matting and entanglement.

The present invention relates to an apparatus and process for imparting crimp to synthetic thermoplastic yarns and particularly to an improvement in the apparatus and processes based upon the use of a fluid jet for imparting the crimp to the yarn.

The objects of this invention are to provide an apparatus and process for imparting an improved crimp to synthetic thermoplastic yarns, which crimp is three-dimensional, uniform and free from loops, knots and matting, and which yarn, when crimped, has improved bulk and coverability and the products, such as carpets, made from such yarns have improved appearance and hand. Further objects of this invention are to provide such an apparatus and process which is economical in that, among other things, it has relatively low power requirements, requires a minimum of operator attention, and has a minimum waste resulting from damaged or improperly bulked yarns.

In accordance with this invention, the above objects have been achieved by providing a fluid jet type bulking apparatus, in which the yarn and the bulking fluid issue from a nozzle into a bulking chamber that is partially closed at the bottom by means such as a screen or screen-like member which permits the bulking fluid to exhaust therethrough while the yarn is deposited in a folded condition thereon. The bulking fluid has sufficient heat to plasticize the yarn in the time the yarn is exposed to the bulking fluid and has sufficient energy to move the yarn laterally within the bulking chamber so that, as the yarn advances endwise, it is laid in a random manner at the bottom of the bulking chamber. The bulking chamber is dimensioned both in length and in cross-section relative to the particular yarn being processed to insure lateral movement of the yarn in the bulking chamber at a frequency and amplitude that provides a uniformly crimped yarn without excess entanglement, looping or knotting. The jet unit is mounted with the exit of the bulking chamber as close as reasonably possible to the screen. The jet unit is also mounted for movement yieldably away from the screen and is biased or loaded so that it is resiliently held in its operative position relative to the screen.

With the above and other objects in view, a preferred embodiment of the present invention is hereinafter described with reference to the accompanying drawings, in which:

FIG. 1 is a schematic illustration of apparatus embodying the present invention and for practicing the process thereof.

FIG. 2 is a fragmentary vertical sectional view of the jet unit of the apparatus of FIG. 1.

FIG. 3 is a fragmentary view, partly in section and partly in elevation, of the jet unit of the apparatus of FIG. 1, together with the supporting means therefor.

With reference to the drawings, the unbulked yarn Y is fed from a source (not shown) by yarn feed rolls **1** to a bulking or jet unit **2**. The bulked yarn BY from the jet unit **2** is deposited on a screen **3** entrained about a pair of spaced rollers **4** and **5** and driven to advance the screen in the direction of the arrow A. The roll **4** is designed to support the screen **3** while permitting a bulking fluid to pass radially therethrough and for this purpose may comprise corrugations arranged on edge radially of the roll **4** such as in the couch rolls of a fourdrinier machine. The bulked yarn is pulled from the screen **3** by nip rolls **6** which cooperate with draw rolls **7** to impart an after-stretch to the yarn. From the draw rolls **7**, the bulked yarn passes to a winder (not shown).

A specific embodiment of the jet unit **2** is illustrated in FIG. 2. As shown, the jet unit **2** comprises a jet body **8** having an axial bore **9** which includes a cylindrical portion **10** in the upper end of the bore **9** that leads into a downwardly converging section consisting of an upper frusto-conical surface **11** and a lower frusto-conical surface **12** that is sharper or more acute relative to the axis of the jet unit **2** than the surface **11**. The bore **9** also includes what is herein called a capillary tube **13** and a bulking chamber **14**, both of which are preferably cylindrical and which are disposed in turn at the output end of the surface **12** so that the capillary tube **13** constitutes in effect a nozzle opening into the bulking chamber **14**.

Within the cylindrical portion **10** of the bore **9** there is mounted a yarn tube **15** that is accurately positioned axially of the bore **9** by a pair of spaced positioning surfaces **16**. The tip **17** of the yarn tube **15** is frusto-conical with a cone angle corresponding to or slightly less than the cone angle of the lower frusto-conical surface **12** of the bore **9** and is spaced from the surface **12** to provide a downwardly converging annular passage **18** between the same. The yarn tube **15** is positioned endwise in the bore **10** by a flange **19** overlying the top surface **20** of a reduced and externally threaded upper portion **21** of the jet body **8**. A cap **22** is provided with an internally threaded skirt **23** that is threaded onto the reduced upper portion **21** of the jet body **8** and with a cover portion **24** that overlies the flange **19** and compresses the same against the surface **20**. A shim **25** is interposed between the flange **19** and the surface **20** to locate the yarn tube **15** accurately endwise of the bore **9**.

The cap **22** has a thread eye **26** seated in the cover portion **24** concentrically thereof. The yarn tube **15** has an axial yarn bore **27** through which the yarn Y passes. The thread eye **26** may be enlarged relative to the yarn bore **27** to facilitate threading and the yarn bore **27** may be counterbored or flared at top **28** to provide a smooth path into the same.

The outer diameter of the yarn tube **15** is substantially smaller than the diameter of the cylindrical portion **10** of the bore **9** to provide an annular chamber **29** that communicates with the annular passage **18**. Bulking fluid, which is preferably and is for convenience hereinafter referred to as steam, is supplied to the chamber **29** through a bore **30** in the jet body **8**, which bore **30** connects with a bore **31** in a supporting arm **32** that carries the jet unit **2**. The bore **31** is in turn connected by a fitting **33** (FIG. 3) and flexible conduit **34** to a source of fluid under pressure (not shown). Preferably, the conduit **34** is adapted to be connected selectively to the source of the bulking

fluid (e.g., steam) or to a source of relative low pressure fluid (e.g., air at 10 p.s.i.) which will cause the jet to aspirate and thereby facilitate stringing the yarn Y through the yarn bore **27** of the yarn tube **15**.

The jet body **8** is positioned directly over the roller **4** with its bottom surface **35** and thus the exit of the bulking chamber **14** positioned immediately upon the screen **3** and is pivotally mounted for movement toward and from the screen **3**. For pivotally mounting the jet body **8**, it is secured by bolts **36** to one end of the supporting arm **32** which is pivotally mounted at its other end on a pivot rod **37** on an axis parallel to the axis of the roller **4**. The jet body **8** is thus free to move about the axis of the pivot rod **37** toward and away from the screen **3**. Pivotal movement of the jet unit **2** in the direction toward the screen **3** is limited by stop means comprising a bracket **38** secured to the jet body **8** and carrying a stop screw **39** that engages a bracket **40** secured to a support **41**. The jet unit **2** is biased to its stop position by gravity which, if necessary, may be supplemented by means such as the illustrated air cylinder **42** secured to the support **41** and having its piston **43** bearing on the bracket **38**.

EXAMPLE

As an example of a specific embodiment of the present invention, there was provided a cylindrical bulking chamber **14** that was 0.250" in diameter and 0.250" deep. The capillary tube **13** was 0.093" in diameter and 0.130" in length. The bore **27** of the yarn tube **15** was 0.046" in diameter and the cone angle, that is, the included angle between the side walls at diametrically opposed points, of the conical surface **12** and of the tip **17** of the yarn tube **15** was 40°. The yarn tube **15** was positioned endwise of the jet with the bottom edge thereof at the level of the input of the capillary tube **13**. The stop screw **39** was adjusted to support the jet body **8** with the bottom surface thereof 0.005" off the screen **3**. The jet body **8** was biased downwardly into its stop position by a total force of two pounds.

The yarn feed rolls **1** were operated to feed yarn at a rate of 460 feet per minute, while the screen **3** was operated at a surface speed of 133 feet per minute. The bulking fluid was saturated steam at 100 p.s.i., the temperature of which was 170° C. Steam consumption was about 25 pounds per hour.

A 3200 denier, 210 filament, untwisted, disperse-dyeable polypropylene yarn was processed on the above apparatus. At breakage, this yarn had a tenacity of fourteen pounds and an elongation of 210 percent. The yarn issued from beneath the jet body **8** as a smooth and uniform ribbon on the screen **3** and was free from loops, knotting, excessive entangling and fused filaments. The bulked yarn had a crimp level of about twelve crimps per inch and a scoured skein shrinkage of thirteen percent. The denier of the bulked yarn was about 4300. The crimp was curvilinear, three-dimensional and random. After drawing or stretching the bulked yarn between the rolls **6** and **7** at a constant tension of 80 grams, the yarn was wound on a package and was subsequently tufted into a carpet. In contrast to carpet made from the same yarn but bulked by a conventional stuffer box process, which yarn had about 19–22 crimps per inch and a bulk denier of 3750, the carpet made from the yarn processed in accordance with this invention had a fuller hand, and improved lustre, pattern definition, pattern retention, cover, and cleanability.

It has been found that yarn having filaments with non-circular cross section will have a higher apparent bulk level than yarn having filaments that are circular in cross section. Without limiting the invention to any particular theory, the higher apparent bulk level of the yarns with filaments of non-circular cross section would appear to be a result of a more random crimp than can be achieved with filaments that are circular in cross section.

OPERATION

While the scope of the present invention is not limited to a particular theory of operation, the following theory relative to the bulking action may explain the operation and facilitate an understanding of the invention.

The crimp that is imparted to the yarn by the above bulking apparatus is produced by a random endwise collapse or folding the individual filaments of the yarn as they are depositied in the bottom of the bulking chamber **14** and form a filament pad. The pad of filaments is compressed against the screen **3** by the pressure differential across the pad, that is, between the static pressure in the bulking chamber **14** and the pressure below the screen **3**, which may be atmospheric or lower such as by using a suction internally of the roller **4** as in the conventional couch roll as used for example in a fourdrinier machine. Compression of the filaments in the pad increases the crimp amplitude by collapsing the vertical component of the folded or crimped filaments. The crimp is further enhanced by the compaction and deformation of the filaments through the "ironing" effect as they pass under the meeting edge between the bottom surface **35** of the jet body **8** and the front wall of the bulking chamber **14**, that is, the edge **44** (FIG. 2), and under the bottom surface of the jet body **8**.

While the speed at which the yarn is advanced through the jet unit **2** is determined by the feed rolls **1**, the force that advances the yarn is provided by the impingement of the stream jet upon the yarn. In addition to advancing the yarn endwise, the steam jet also serves to open or balloon the yarn and thus separate the individual filaments as the steam jet expands upon issuing from the capillary tube **13** into the bulking chamber **14**. In order to permit the yarn to open, it is preferably untwisted although some twist can be accommodated.

A further function of the steam is to plasticize the yarn. To process the yarn through the jet unit **2** at the fastest possible rate, the residence time of the yarn in the jet and thus the exposure time of the yarn to the steam are very limited. Steam is the preferred bulking fluid rather than, for example, heated air because it has a higher heat content. The steam temperature is selected initially to effect plasticizing of the particular yarn being processed within the exposure time designed into the process. Because of the temperature drop through the expansion of the steam and the dissipation of the heat in the jet unit **2**, and because of the momentary exposure of the yarn to the steam, the line temperature of the steam may be above the melting point of the polymer. With polypropylene yarn that was processed in accordance with the above example, good results were achieved with steam at 170° C. even though the melting point of the polymer is about 164° C. and the orientation temperature is about 160° C. Theoretically, up to the point where fusion or loss of orientation of the filaments occurs, the crimp level improves as the steam temperature is increased and the yarn is thus made more plastic. The steam pressure must be sufficient to provide adequate velocity through the capillary tube **13** and to effect the desired bulking action. Steam is also preferably dry. Therefore, since the maximum steam velocity through the capillary tube **13** is achieved at a lower pressure than that of the saturated steam at the desired temperature, the desired steam temperature becomes the controlling factor.

In addition to advancing, ballooning and plasticizing the yarn, the steam, which issues from the capillary tube as a high velocity jet, also effects lateral movement of the yarn in the bulking chamber, which, as discussed below, is believed to be the factor in determining the manner in which the yarn is folded or deposited in the pad at the bottom of the bulking chamber and thus determines the crimp frequency. This lateral movement of the steam jet in the bulking chamber is believed to be produced by the unbalanced condition that results at the joining of the steam and

yarn at the input of the capillary tube. In lieu of or in addition to the lateral movement produced by the unbalanced condition, there is also the fact that the steam seeks to escape through the filament pad at the bottom of the bulking chamber **14** along the path of least resistance. At any one moment, this path of least resistance occurs at one point on the pad. However, as the steam jet exits through this path and it shifts the yarn into and thus begins to build up that portion of the pad. The density of the pad at that point and thus the resistance to the passage of steam increases so that the path of least resistance shifts to another point on the pad and the steam jet as well as the yarn shift to that point.

As the steam jet shifts about in the bulking chamber, it defines a yarn path that is continuously increasing and decreasing in length. Since the length of yarn in the bulking chamber is at any one time instant fixed by the yarn feed rolls **1** which limit the rate at which the yarn is fed and by the bottom surface **35** of the jet body **8** which clamps the yarn against the screen **3**, that length of yarn is alternately relaxed and extended as the yarn path is increased and decreased. Any one increment of a filament is thus laid in the pad at the bottom of the bulking chamber as the length of the yarn path decreases and is pulled from it as the length of the yarn path increases. In view of the fact that the rate at which the yarn is advanced endwise is relatively slow in comparison to the rate at which it is moved laterally, the filament increment is thus moved about for a period of time before it is finally deposited in the filament pad at the bottom of the bulking chamber. The increment of yarn is finally deposited when, as the feed of the yarn continues, the length in the bulking chamber becomes sufficiently long to accommodate the lateral movement and there is an excess of yarn so that the filament increment remains in the pad in the condition in which it was finally laid. This increment of filament then moves with the screen **3** under the bottom surface **35** of the jet body and becomes the clamping point of the yarn. Inasmuch as the lateral movement is random, the manner in which the filaments are laid in the pad and the length of filament required to accommodate any particular lateral movement are also random. The resulting folds and thus the crimp of the filaments are therefore random and three dimensional.

DIMENSIONS

The manner in which the individual filaments are laid in the pad at the bottom of the bulking chamber is affected by the dimensions of the bulking chamber. The bulking chamber should be large enough in diameter to permit the yarn to balloon and to move about laterally but small enough so that the steam jet will be continuously deflected at a relatively small amplitude and the yarn thereby moved about with the filaments thereof laid in the pad at a relatively high crimp frequency. If the diameter of the bulking chamber is too large relative to the yarn, a lower crimp level and excessive looping will result. The length of the bulking chamber is also significant. Turbulence is developed if the bulking chamber is too long relative to its diameter so that, in view of the normal expansion profile of the steam jet as it issues from the capillary tube **13** into the bulking chamber **14**, the edges of the steam jet impinge upon the side wall of the bulking chamber. At the same time, the increased expansion afforded by the longer bulking chamber lowers the temperature of the steam and dissipates its energy. When the length of the bulking chamber is too short, there is no opportunity for lateral deflection of the steam jet so that it continuously impinges at high velocity in the limited area directly below the opening of the capillary tube **13**. In a bulking chamber that is too short, there is fusion of some of the filaments, which is probably caused by the direct and prolonged impingement of the jet upon the filaments which lie directly beneath the opening of the capillary tube, which filaments are thus heated to a fusion temperature. At the same time, the lower crimp level is probably caused by the insufficient heating and plasticizing of those filaments which are not directly beneath the opening of the capillary tube, or by the loss of heat and energy by excessive expansion and turbulence in the jet.

To illustrate the limits on the diameter of the bulking chamber that is properly dimensioned relative to an unbulked polypropylene yarn of 3200 denier and 210 filaments, a bulking chamber three-eighths inch in diameter and one-quarter inch deep and operated under the same conditions as in the above example, resulted in an erratic operation in which the jet unit **2** pulsated noticeably relative to the screen. The bulked yarn issued from beneath the jet in pulses and had a low crimp level and some fused filaments. This is in contrast to the operation of the jet body **2** having a bulking chamber which, as in the above example, was one-quarter inch in diameter and one-quarter inch deep. In the example, the bulked yarn issued from beneath the jet unit **2** in a smooth ribbon of uniform density and had a uniform and high crimp level and was entirely free from fused filaments. A bulking chamber that was one-eighth inch in diameter would not operate when the clearance relative to the screen was below 0.010" because the bulking chamber became plugged by an excessive filament pad and the steam exhausted through the yarn tube and would not feed the yarn. As the clearance of the jet with the one-eighth inch diameter bulking chamber was increased above 0.010", it initially produced a bulked yarn with a large number of fused filaments and then produced a bulked yarn that was lumpy, matted and badly twisted and tangled.

The limits on the depth of the bulking chamber are illustrated by the results obtained when the bulking chamber was increased in depth from one-quarter inch. When a one-quarter inch diameter bulking chamber was increased in depth from one-quarter inch to three-eighths inch, the jet unit would not operate unless there was a clearance of over 0.020" between the bottom surface **35** and the screen **3**, and then produced only a badly tangled and matted bulked yarn. When the depth of the bulking chamber was decreased from one-quarter inch to one-eighth inch, the bulked yarn that was produced was badly fused, even when the steam pressure was reduced to 80 p.s.i. which has a steam temperature at saturation of only about 163° C. With a bulking chamber that was three-eights inch in diameter, when the depth was increased above three-eighths inch, erratic operation and a lumpy and knotted yarn resulted and, when the depth was reduced below one-eighth inch, there was also produced an erratic operation and a bulked yarn that was tangled and had a large number of fused filaments. Operation could not be improved by varying the steam pressure.

The capillary tube **13** which, as noted above, functions as a nozzle, acts to confine the yarn and to provide a linear path for the yarn and steam after impingement and thus smooth the flow of the steam relative to the path of the yarn. For these reasons, and also to minimize the expansion of the steam as it passes from the annular passage **18** into the capillary tube **13**, the tube **13** is made as small as possible. Preferably, the diameter of the capillary tube **13** is smaller than the diameter of the bulking chamber **14** by an amount sufficient to provide a nozzle-like opening into the bulking chamber and is larger than the bore **27** or internal diameter of the yarn tube **15** by an amount sufficient only to provide an adequate effective area of the annular passage **18**. The diameter of the bore **27** is large enough to provide for moving the yarn freely therethrough but is small enough so that the yarn will substantially plug the same and thereby prevent excessive escape of steam up the bore **27**. As hereinafter discussed, the bottom of the yarn tube **15**, that is, the annular end **45**, is disposed at the level of the input end of the capillary tube **13**. Thus the minimum diameter of the capillary tube **13** that can be achieved is the diameter of the bore **27** plus the width of the end **45** and the opening of the

annular passage 18, which is itself a function of the cone angle of the surface 12 and tip 17. The minimum diameter of the capillary tube 13 is also limited by the mechanical consideration that, in order to provide uniformity in readily reproducible jet units, it is desirable to provide a small annular flat at the end 45 rather than to try to form it to a sharp edge.

The length of the capillary tube 13 can be varied within a relatively wide range since it need only be long enough to provide for intermingling the steam and yarn and to smooth the flow, and to provide sufficient exposure time between the same to plasticize the yarn. A length of 0.130", as in the above example, is sufficient. Increasing the length above this amount produced no noticeable effects upon the crimp level or characteristics although too long a length causes excessive pressure drop and excessive escape of the steam up the bore 27 thereby stopping the yarn feed. Decreasing the length appreciably below this amount (e.g., one-half) resulted in an erratic operation with excessive entangled filaments.

The location of the end 45 of the yarn tube relative to the upper end of the capillary tube 13 is also significant. Preferably, the end 45 is disposed at the same elevation as the entrance end of the capillary tube 13. When so located, the steam forms a smooth and linear jet issuing from the capillary tube 13 into the bulking chamber 14. When the end 45 is below the level of the entrance end of the capillary tube 13, there is apparently a surface effect which causes the jet to adhere to the wall of the tip 17 of the yarn tube 15 and thus to follow onto the end 45 and directly into the yarn and there is produced some turbulence and a reduced bulking efficiency. At the same time, in order to obtain the same effective area in the annular passage 18, a larger capillary tube 13 is required when the end 45 is below the level of the entrance end of the capillary tube 13 than when it is at that level. When the end 45 is located above the level of the entrance end of the capillary tube, there is produced an increasing level of turbulence, presumedly because the effective nozzle is thus raised from the input end of the capillary tube.

The effective area of the annular passage 18 is the minimum opening between the surface 12 of the jet body and the tip 17 of the yarn tube 15 which, with the end 45 of the yarn tube 15 at the level of the input end of the capillary tube 13, is the width of the annular passage 18 at the meeting edge between the surface 12 and the capillary tube 13 in the direction normal to the surface 12. With a given diameter of the bore 27 of the yarn tube 15 and of the capillary tube 13 and thus a constant annular opening of the passage 18 into the capillary tube 13, the effective area of the passage 18 varies with the cone angle of the tip 17 and of the surface 12. As the cone angle decreases or becomes more acute relative to the axis of the yarn tube, the effective area becomes more nearly equal to the difference between the diameters of the bore 27 and the capillary tube 13. Since the capillary tube is preferably made as small as practical, the cone angle is also made as sharp or as acute as practical. A sharp cone angle also provides a smooth flow from the passage 18 into the capillary tube 13 and a relatively gentle or smooth impingement of the steam on the yarn. On the other hand, as noted above, mechanical considerations limit the extent to which the tip 17 can be formed to a point. At the same time, there is no noticeable effect upon the crimp level of the bulked yarn when the cone angle is varied in the neighborhood of 20° to 40°. The preferred angle is about 30°.

The tip of the yarn tube 15 is positioned accurately relative to the axis of the jet body 8 so that it is concentric with the lower frusto-conical surface 12. Lack of concentricity varies the width of the annular passage 18 at the different points around the tip 17, Non-uniformity in the annular passage 18 results in a non-uniform flow of steam through the passage and thus a non-uniform impingement of the steam jet on the yarn, which in turn causes vortexing and thus false twisting and knotting of the yarn. In extreme cases, a concentrated jet as distinguished from a uniform annular jet will split the yarn into two separate groups of filaments, which are false-twisted in opposite directions.

In the above example, a high and uniform crimp level was obtained with a steam volume of about twenty-five pounds per hour. An insufficient volume of steam will not plasticize the yarn within the same temperature and time considerations and will not effect sufficient lateral movement to provide a high crimp level. An excessive volume of steam does not contribute to the crimp level and also causes fusion because of overheating of some filaments and causes excessive entanglement through turbulence.

The bottom face 35 of the jet body 8 is preferably positioned as close as possible to the screen 3. Because the jet could mechanically damage the screen 3 if it rode on the screen surface without yarn passing through and to accommodate the run-out that is inherently present in any commercial quality roller, the spacing is limited by the stop screw 39 to about 0.005". One of the objectives of the limited spacing is to reduce the gap between the screen 3 and the edges of the bulking chamber 14 at the output end such that the gap can be readily covered or plugged by the pad of yarn in the bottom of the bulking chamber 14. When the gap is increased in the above example to about 0.010", some portion of the steam jet can escape laterally between the screen 3 and the bottom surface 35 of the jet body rather than through the screen 3. In addition to reducing the bulk level, the laterally escaping steam pulls filaments from the ribbon of bulked yarn to form undesirable loops in the yarn. A further objective of the relatively small gap is to effect ironing of the ribbon of bulked yarn on the screen 3 as it passes under the bottom surface 35. The spacing may be varied relative to the density of the ribbon of bulked yarn so that the bottom surface 35 in operation effectively rides on the yarn and not on the stop screw 39.

While the spacing of the jet body 8 off the screen 3 is important, it also requires that for satisfactory operation the jet unit 2 be yieldable relative to the screen. With a small bulking chamber 14 that is very closely spaced relative to the screen 3 and a relatively rapidly moving yarn, any momentary delay in the removal of the yarn from the bulking chamber 14 quickly tends to fill the chamber with yarn. If the bulking chamber is not almost instantaneously relieved of the excess accumulation of yarn, the bulking operation is automatically shut down because, when the yarn in the bulking chamber becomes too dense, the steam is exhausted up the board 27 of the yarn tube 15 and thus ceases to feed the yarn. With a jet unit 2 in accordance with this invention, as the yarn pad in the bottom of the bulking chamber begins to increase in thickness and density, the back pressure in the bulking chamber and thus the force tending to lift the jet unit 2 off the screen 3 also increases. By yieldably mounting the jet, it is thus free to lift off the screen and to disgorge the accumulated excess yarn.

In order to provide a satisfactory crimp, a bias or loading is required to urge the jet unit 2 into its operative position, which bias or loading is provided by gravity and by the air cylinder 42. Generally, within the operative range, increased loading increases the bulk level by increasing the crimp amplitude and frequency. Presumedly, this is because the gap around the edge of the bulking chamber 14 at the screen 3 is more tightly sealed as the loading is screened, or because of the increased ironing effect on the ribbon of bulked yarn on the screen as the pressure between the surface 35 of the jet body 8 and the screen 3 is increased, or because of the increased deformation of the engaged filaments as they pass under the edge 44 of the bulking chamber. When the loading is too light, the jet unit 2 tends to float relative to the screen 3 so that

the steam can exhaust laterally through the gap between the bottom surface 35 and the screen rather than through the screen 3. As noted above, lateral exhausting of the steam decreases the bulk level that is achieved and also pulls filament loops from the ribbon of bulked yarn. When the loading is so high that the jet unit cannot lift relative to the screen and thus disgorge any accumulation of yarn in the bulking chamber, the bulking process stops automatically. With the apparatus used in the above example, good bulking can be achieved with a loading as low as one or two pounds on the jet unit 2. Loadings as high as ten pounds have also been used with good results, although, at this level, termination of the bulking process by plugging of the bulking chamber occurs too frequently for commercial operation.

The screen 3 is preferably quite fine to provide a relatively smooth surface on which the yarn is laid but yet is sufficiently open to provide for escape of the steam therethrough. The openess of the screen is significant in that a screen that is too open permits the filaments to be blown through the holes between the screen wires. The filaments thus form loops that are merely draped over the screen wires. Aside from the fact that this does not produce a three-dimensioned crimp at a high crimp frequency, the ribbon of yarn cannot be easily lifted from the screen and has numerous pulled filaments as individual filaments thereof are snagged on the screen or pinched between the crossing points of the screen wires. If the screen is not open enough, the steam cannot readily pass through the same so that the velocity through the bulking chamber and thus the lateral movement of the yarn in the bulking chamber are reduced. The lateral escape of the steam between the bottom surface 35 of the jet body 8 and the screen 3 is also increased as the openness of the screen is decreased. A screen such as a 60 x 60 mesh screen with wires that are 0.009" in diameter and which has approximately 21% open area, is not sufficiently porous to provide satisfactory bulking, whereas a screen such as a 15 x 15 mesh screen with wires that are 0.020" in diameter and which has 49% open area is too coarse and too open. The preferred screen is 35 x 35 mesh with screen wires about 0.010" in diameter and an open area of approximately 40%.

In the above example, the yarn input feed rolls 1 were operated at 460 f.p.m., while the screen was operated at 133 f.p.m. Using the same speed ratio, the yarn input speed can be varied significantly without appreciably varying the crimp level of the bulked fiber. Input speeds as high as 800 f.p.m. have been used successfully. The speed of the screen can also be significantly varied relative to the yarn input speed without altering the crimp level appreciably although when it is operated faster than about one-third of the speed of the input, the crimp level begins to decrease and if it is operated slower than about one-sixth the speed of the input, the crimped yarn issued from beneath the jet at a rate that is so high that the yarn will not stay on the screen and thus control is lost.

While the bulking chamber 14 in accordance with the above embodiment is cylindrical, a bulking chamber that is square is not only satisfactory but in some respects may be preferred. With a square bulking chamber, all of the filaments of the yarn engage the edge 44 in the same manner, whereas with the cylindrical bulking chamber, the filaments at the side edges of the ribbon of bulked yarn on the screen 3 engage a portion of the edge 44 that converges in the direction in which the screen is traveling.

In the disclosed embodiment of the invention, there is a single jet unit 2. It will of course be obvious that in a commercial operation a plurality (e.g., 60) of the jet units 2 will be arranged in a transversely aligned relation relative to the roller 4 in a single machine.

The present disclosure deals specifically with polypropylene yarn but it will also be obvious that the disclosed process and apparatus can be used with other synthetic thermoplastic yarns by changing the operating conditions in accordance with the plasticizing characteristics of the selected yarn. Examples of such other yarns would be polyamides, polyesters and polyacrylonitriles.

What we claim and desire to protect by Letters Patent is:

1. Bulking apparatus for bulking multi-filament yarns of thermoplastic material, comprising,
   - a jet body having a bulking chamber open at one end and nozzle means opening into the bulking chamber at the end opposite from the open end,
   - screen means movable endlessly in one direction,
   - feed means for feeding a yarn to be bulked at a rate substantially in excess of the speed of the screen means,
   - yarn guide means for directing yarn from said feed means into said nozzle means,
   - means for supplying to said nozzle means a bulking fluid for advancing the yarn endwise into said bulking chamber and for plasticizing the same,
   - means for mounting the jet body for movement toward and from the screen means and for locating the same in a stop position with the open end of the bulking chamber sufficiently close to the screen means substantially to preclude the exhaust of the bulking fluid from said bulking chamber through the gap between the open end of the bulking chamber and the screen means and thereby to confine the exhaust of the bulking fluid to the area of the screen means opposed to the open end of the bulking chamber, whereby the yarn is deposited in a ribbon on the screen means and is compacted between the screen means and the jet body as it is advanced by the screen means.
   - and bias means for urging the jet body toward the screen means into the stop position.

2. Bulking apparatus in accordance with claim 1 in which said nozzle means comprises a capillary tube axially aligned with and opening into said bulking chamber, through which the yarn and bulking fluid flow.

3. Bulking apparatus in accordance with claim 2 in which said nozzle means further comprises a converging annular passage opening into the end of the capillary tube opposite from said bulking chamber and about said yarn guide means.

4. Bulking apparatus in accordance with claim 3 in which said jet body has a bore axially aligned with said capillary tube and communicating with said nozzle means, said yarn guide means comprises a yarn tube disposed in and coaxially of said bore, said yarn tube having an outer dimension substantially less than the dimension of the bore and said means for supplying bulking fluid to said nozzle means comprising an annular passage between the bore in the jet body and the outer wall of said yarn tube.

5. Bulking apparatus in accordance with claim 4 in which the yarn output end of the yarn tube is disposed substantially level with the yarn input end of the capillary tube.

6. Bulking apparatus in accordance with claim 4 in which the annular passage is defined by the tip of the yarn tube and a frusto-conical surface between the capillary tube and the bore in the jet body, said tip of the yarn tube having a cone angle substantially conforming to the cone angle of said frusto-conical surface and disposed in spaced relation thereto.

7. Bulking apparatus in accordance with claim 6 in which the included cone angle of the frusto-conical surface is between substantially 20° and 40°.

8. Bulking apparatus in accordance with claim 6 in which said yarn tube has a yarn bore the diameter of which is the minimum diameter required for a selected yarn to pass freely therethrough and the diameter of said capillary tube is equal to the diameter of the yarn bore and the opening of the annular passage into the capillary tube.

9. Bulking apparatus in accordance with claim 8 in which said bulking chamber has a cross sectional dimension that is substantially four to six times the dimension of the yarn bore in said yarn tube.

10. Bulking apparatus in accordance with claim 8 in which said capillary tube is at least substantially as long as its cross sectional dimension.

11. Bulking apparatus in accordance with claim 1 in which said bulking chamber is dimensioned relative to the opening of said nozzle means to provide for expansion of the bulking fluid from the opening of said nozzle means to the open end of said bulking chamber without impingement of the expanding jet of the bulking fluid at its periphery with the side wall of the bulking chamber.

12. Bulking apparatus in accordance with claim 1 in which said bulking chamber is dimensioned relative to said nozzle means to provide for lateral movement of the yarn within the bulking chamber for folding the filaments of the yarn as they are deposited on said screen means at the open end of said bulking chamber but to prevent lateral movement of the yarn of a magnitude sufficient to cause knotting.

13. Bulking apparatus in accordance with claim 1 in which said screen means has substantially between 20% and 40% open area.

14. Bulking apparatus in accordance with claim 1 in which said feed means comprises a pair of conveying elements adapted to feed yarn at a rate substantially between three and six times as fast as the speed of said screen means.

15. Bulking apparatus in accordance with claim 1 in which the means for mounting the jet body includes a stop position less than 0.010" off said screen means and the jet body is biased toward said stop position by a force of substantially two pounds or more.

16. Bulking apparatus in accordance with claim 1 adapted for bulking polypropylene yarn of substantially 3200 denier and 210 filaments, said apparatus having a bulking chamber with a lateral dimension of substantially 0.250 inch and a depth of substantially 0.250 inch, said nozzle means having an opening into said bulking chamber that is coaxial thereof and is substantially 0.093 inch in diameter, said jet body being disposed with the open end of said bulking chamber spaced from said screen means a distance less than about 0.010 inch and being movable in a direction from said screen means and biased toward said screen means by a force between about 2 and 8 pounds.

References Cited

UNITED STATES PATENTS

2,379,824	-7/1945	Mummery.
2,634,491	-4/1953	McDermott.
3,036,357	5/1962	Cook et al.
3,055,080	9/1962	Claussen et al.
3,255,508	6/1966	Weiss et al.
3,341,912	9/1967	Dyer et al.

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U.S. Cl. X.R.

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