Oct. 12, 1971 M. H. HORN 3,611,698

HEAVY DENIER CRIMPED AND ENTANGLED YARN

Filed March 4, 1970 3 Sheets-Sheet 1

FIG. 2

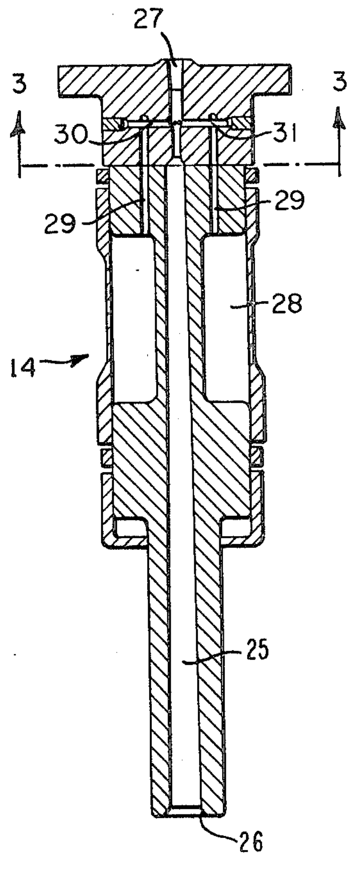


FIG. 1

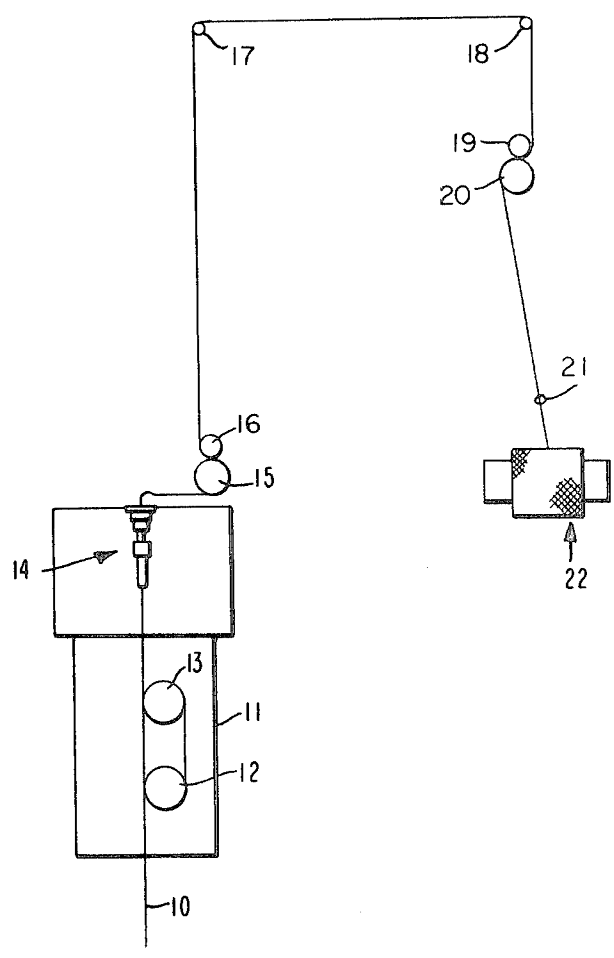


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FIG. 3

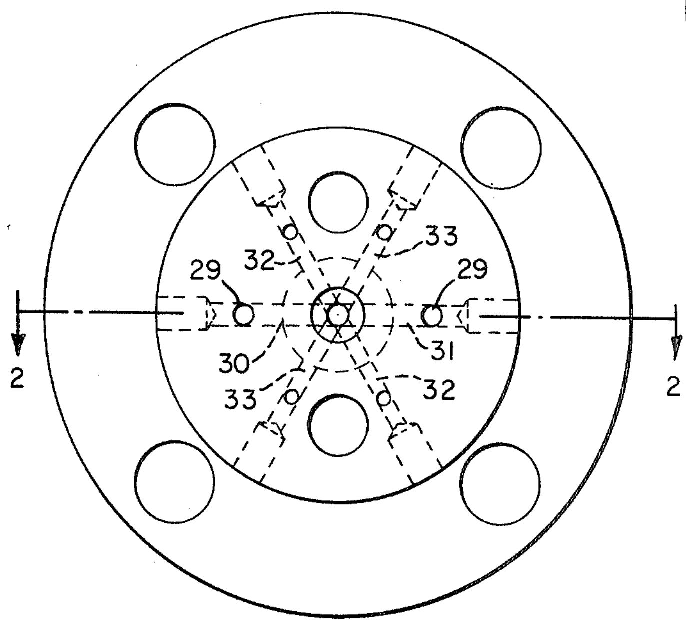


FIG. 4

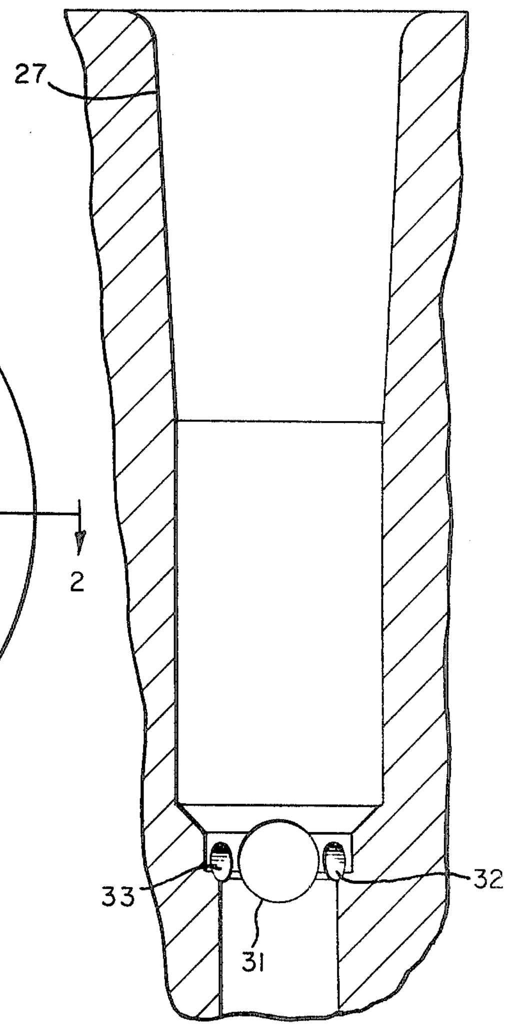


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FIG. 5

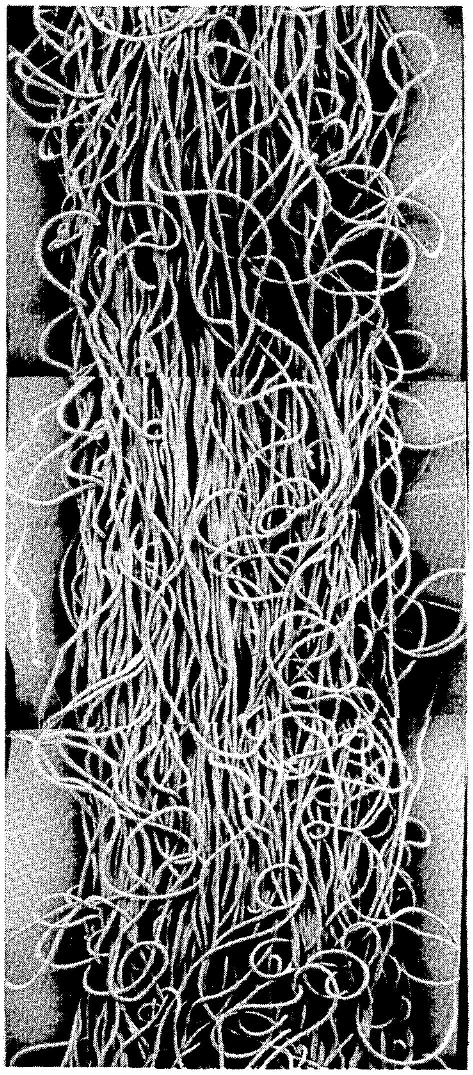
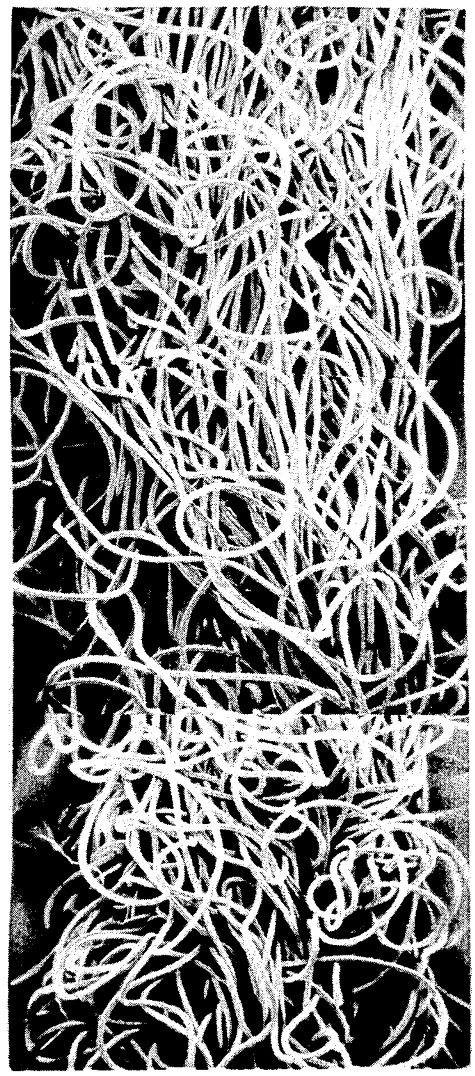


FIG. 6



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# HEAVY DENIER CRIMPED AND ENTANGLED YARN

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U.S. Cl. 57—140 R 10 Claims

## ABSTRACT OF THE DISCLOSURE

Heavier denier crimped yarns of continuous filaments are disclosed wherein filament crimp and entanglement provide a combination of elastic and stabilized bulk which is particularly desirable for tufted, cut-pile fabrics. The yarn bulk and cohesiveness is such that there is little blooming or expanding of the cut ends and the tufts remain upright, so that good tuft definition is maintained when carpets are subjected to heavy traffic. An economical fluid jet process for producing the novel yarn is disclosed.

## BACKGROUND OF THE INVENTION

Synthetic, continuous filament yarns which have been textured by various mechanical or fluid-jet bulking processes are used extensively in loop-pile, tufted carpets. For cut-pile tufts, however, additional twisting and twist-setting operations have been necessary if the tufts are to retain their individuality and bulk so as to provide a satisfactory appearance in service. These additional, expensive operations are unnecessary when using the yarn of the present invention.

## SUMMARY OF THE INVENTION

The product of this invention is a heavy denier crimped yarn of at least 50 crimped continuous thermoplastic filaments interentangled in a structure characterized by laterally-oriented filament loops which penetrate within said structure and bind other filaments in place in the yarn. The filaments have at least four crimps per inch of significant size which provide an elastic stretch of about 8% to 40%, preferably 13% to 30%, when the yarn is subjected to a load of 0.1 gram per denier (g.p.d.) in the elastic stretch test described subsequently. This elastic stretch is provided in the presence of a filament interentanglement which provides at least 5% of stabilized yarn bulk, preferably 15% to 30%, when under a load of 0.1 g.p.d. The bulk is stabilized by filament entanglement which provides less than 3.5 inches (preferably 0.25 to 2.0 inches) mean separation distance of filament groups under a one-pound load in the lateral pull-apart test. The uniformity of entanglement is such that the standard deviation of individual determinations of separation distance in the pull-apart test is less than 0.5, preferably less than 0.4, times the mean separation distance for ten determinations at random intervals along the yarn. The yarn is substantially free from any twist or external filament wraps sufficient to have appreciable effect on values obtained in the pull-apart test.

The denier of the yarn depends upon the intended use. Yarns having stabilized bulk deniers of 1,000 to 7,000 denier are used for tufted cut-pile carpets. Stabilized bulk denier refers to the denier of yarn while under a tension which temporarily removes the elastic stretch without significant removal of bulk-giving entanglement. Filaments of 5 to 20 denier per filament (d.p.f.) are preferably used to prepare this yarn.

The filaments preferably have about 8 to 16 crimps per inch of persistent, random, three-dimensional, curvilinear configuration. However, crimps of sinusoidal or sawtooth configuration can also provide the required stretch, i.e., a stretch length under 0.1 g.p.d. load which is about 8% to 40% greater than the retracted length of the yarn after removal of the load.



## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of suitable apparatus and process for preparing products of this invention.

FIG. 2 is a side sectional view of a fluid jet device for use in the process, the cross-section being taken along the yarn axis as indicated in FIG. 3.

FIG. 3 is an axial view taken along line **3—3** of FIG. 2.

FIG. 4 is an enlarged sectional view of a preferred configuration for the upper portion of the yarn passage shown in FIG. 1.

FIG. 5 is a greatly enlarged view of fiber entanglement in a yarn prepared as described in Example II.

FIG. 6 is a greatly enlarged view of fiber entanglement in a yarn prepared as described in Example III.

## DETAILED DESCRIPTION

Referring to FIG. 1, substantially twist-free yarn **10** from any convenient source passes into a preheat chest **11**. The yarn makes several wraps about feed rolls **12** and **13**, so that the yarn is preheated, and is fed through fluid jet device **14**. The yarn is abruptly removed from the treating fluid by leading the yarn sideways away from the jet exit to take-up rolls **15** and **16**. The yarn proceeds around guides **17** and **18** to windup feed rolls **19** and **20**, through traversing guide **21**, and is packaged at windup device **22**.

The construction of the fluid jet device is shown in FIGS. 2 to 4. Yarn passageway **25** has an entrance **26** and a venturi-shaped exit **27**. Steam or air introduced into chamber **28** passes through channels **29** to a main pair of opposed jet-stream conduits **30** and **31**. As shown in FIG. 3, there are also two additional pairs of smaller opposing conduits **32** and **33** which intersect the yarn passageway in the same plane as the main pair. The axes of these three pairs of conduits are equally spaced around the yarn passageway, are perpendicular to the axis of the yarn passageway and intersect it at the same point. The opposed fluid jets from the main conduits are essential for producing the products of this invention. The secondary jet streams from the smaller conduits serve to stabilize the position of the yarn between the primary streams and facilitate the preparation of uniformly bulked and entangled products by helping to avoid intermittent regions of higher and lower entanglement. The products of this invention are highly uniform, as indicated by low standard deviation values in the pull-apart test, and provide good tuft uniformity and bulk in use.

The feed yarn must be substantially free of yarn twist and filament entanglement. No twist should be imparted to the yarn aside from that which may be inherently introduced, as in removing yarn from a supply package. Such twist will normally be less than about 0.5 turn per inch (turn per 2.54 cm.). Higher twist or appreciable filament entanglement retards development of the required bulked and entangled structure in the treatment process. The yarn is normally fed to the jet device at speeds of at least 100 yards per minute (91.4 meters/minute), and much greater speeds can be used. The treated yarn is withdrawn from the jet device at a slower speed which provides an overfeed to the jet at least equivalent to the total amount of elastic stretch and stabilized bulk to be introduced by the jet treatment.

Steam, both saturated and superheated, and air are suitable treating fluids. Pressures of about 80 to 125 pounds per square-inch gage (p.s.i.g.) are preferred. Temperatures of about 200° to 260° C. are generally suitable for simultaneously crimping and interentangling 6—6 nylon filaments. The temperature is adjusted, for any particular treatment conditions and filament composition, so that sufficient crimp is produced to provide the required elastic stretch without heating the filaments to the fusion temperature.

For the twist-free product of this invention to have sufficient bulk as a substitute for twist-set bulky yarns in cut-pile carpets, the yarn must have an elastic stretch as defined herein of 8% and preferably 13% to 30% in addition to stabilized bulk. To achieve this level of elastic stretch, the filaments in the bulked yarn must have a crimp of at least 4 crimps/inch (per 2.54 cm.), preferably at least 8 to 16 crimps/inch (per 2.54 cm.) which is preferably a persistent, random, three-dimensional curvilinear crimp.

For such bulky, twist-free yarns to provide acceptable retention of tuft definition in cut-pile carpets wherein twist-set yarns are normally employed, it has been found that the yarn must be sufficiently entangled to have a mean lateral pull-part distance as described herein of less than about 3.5 inches (8.9 cm.) and preferably 0.25 to 2.0 inch. For the yarn to provide acceptable uniformity in appearance and aesthetics, the yarn must be uniformly entangled along its length such that the standard deviation of the pull-apart distance is less than 0.5 times said distance.

The preferred product of this invention possesses a unique combination of a high degree of filament entanglement and three-dimensional, permanent filament crimp. Because of the random complexity of the entangled filament structure required to achieve this high yarn coherency, characterization of the entangled filament configuration is extremely difficult. A close examination of the yarn generally shows the presence of some stress-relieved crunodal filament loops which retain their ring-like configuration upon removal from the yarn, as well as other bulk-giving filament configurations. The high degree of filament entanglement which produces the desired yarn coherency is believed to result primarily from frequent lateral, and sometimes abrupt, penetration of filament loops into the filament bundle. The frequency of crunodal loops, both within the yarn bundle and on its surface, observed in products meeting the limits of this invention is somewhat dependent upon the number of filaments in the yarn bundle and denier per filament. In general, the greater the number of filaments and the lower the denier per filament the fewer the number of filament crunodal loops observed in the product when sufficient entanglement is obtained.

The products of this invention have a relatively low degree of extensibility compared to their high level of usable yarn bulk. Because of the high degree of filament entanglement, under the loads employed for determining elastic stretch, the yarn retains a significantly bulked appearance; such loads are insufficient to completely straighten the filaments. Although the filament entanglement can be permanently reduced by significantly higher loads, which of course gives a further reduction in bulked yarn appearance under load, this requires loads greater than normally encountered in yarn processing and carpet tufting operations. Thus, the yarns retain their high level of stabilized bulk in the finished product. As a result of this high filament entanglement in the yarn bundle, there is little blooming or expanding of the cut ends in tufted, cut-pile fabrics made from these yarns. Thus, these twist-free yarns provide aesthetics comparable to those which presently require the use of bulked, twisted and twist-set yarns.

## TEST METHODS

### Stabilized bulked denier

The stabilized bulked denier is determined from the weight of a yarn length measured under tension of about 0.1 g.p.d. to remove crimp without otherwise stretching the filaments. In the following examples the yarn is conditioned at 72% relative humidity for a minimum of two hours. One end of the yarn is fastened to a hook. For convenience, for a 2600 yarn and higher deniers, a 280±3 gram weight is attached to the other end (a 1200–1500 denier yarn takes a 125±2 gram weight). The weight is attached to the sample for six minutes, and then the sample is transferred to a wall cutter. The wall cutter consists of two electromagnetically operated cutters which cut the yarn simultaneously upon operation of a button. One cutter is located exactly 90 cm. above the other so that the yarn hangs through both cutters with the weight attached. The 90 cm. piece of yarn is weighed on an analytical balance. The decimal point is moved four places to the right for the weight to obtain the denier ($D_s$). The percent stabilized bulk is then calculated from the denier ($D_o$) of the yarn when free of both crimp and bulk as determined from individual filament deniers and number of filaments in the yarn:

$$100(D_s-D_o)/D_o$$

Where feed yarn denier is known, as in the following examples, $D_o$ can be calculated from feed yarn denier correcting for the amount of shrinkage which occurs under the bulking conditions.

### Elastic stretch

Elastic stretch is determined on yarn which has been treated as follows: A 100–105 cm. length of yarn is put into a water bath and boiled at 100° C. for three minutes. The yarn is rinsed in cold water and dried at 100–110° C. for one hour, all under a relaxed condition. The yarn is conditioned at 72% relative humidity for two hours. A 55-cm. length of yarn is fastened to a clamp on the upper end of a 150-cm. vertical board. Fifty centimeters below this clamp is another clamp which is attached to a supported weight of about 0.1 g.p.d. For convenience, in the following examples, for 2600 and higher denier yarns, a 300±3 gram weight is used while a 146±2 gram weight is used for 1200–1500 denier yarn.

The yarn is attached to the weight clamp and the weight is unhooked from its support and allowed to hang at the end of the yarn for three minutes. The weight is then removed and the yarn is allowed to retract for three minutes. The extended and retracted lengths are measured. The percent elastic stretch is calculated by dividing the difference in length by the retracted length and multiplying the result by 100.

### Crimp per inch (CPI)

The yarn is "boiled-off" and conditioned as described above. A section of yarn in a relaxed condition is cut to exactly two inches. A single filament is taken from this yarn section and mounted between two clamps which are approximately two inches apart. The clamps are mounted over a piece of black cloth to facilitate counting the crimps. Only crimps of a size which would significantly affect the stretched length are counted. A crimp is defined as one complete crimp cycle or sine wave. The crimps/inch are calculated by dividing the number of crimps for a single filament by two. Because of the random nature of the three-dimensional crimp, some judgment must be exercised in determining the significant crimp. Abrupt changes in the direction of the filament are looked for.

### Lateral pull-apart test for yarn bundle coherency

This test directly measures the lateral bundle cohesiveness of the yarn. Two hooks are placed in about the center of a yarn bundle to separate it into two groups of filaments. The hooks are pulled apart at 5 inches/min. (12.7 cm./min.) at 90° to the bundle axis by a machine which measures the resistance to separation, such as an Instron® machine. The yarn is pulled apart by the hooks until a one-pound (454-gm.) force is exerted, at which point the machine (Instron) is stopped. The distance between the two hooks is measured. Ten determinations are made, the average taken and the standard deviation determined by normal mathematical procedures. The yarns are usually tested before a "boil-off" treatment; however, in general, little or no difference is found in comparing results between yarns before and after a "boil-off" treatment. The test yarn lengths should be at least 4–6 inches (10–15 cm.) long taken randomly throughout a yarn package.

The products of this invention are relatively free of external filament wraps. A filament wrap is defined as a filament, or filaments, which is wound around the exterior of the filament bundle causing a decrease in bundle diameter. In determining wrap frequency in a length of yarn, any surface wrap surrounding a majority of the filaments is counted. The products preferably have less than one filament wrap per meter and even more preferably as few as 0.09 wraps per meter. In all cases, the distance between wraps is substantially greater than the pull-apart distance, thus showing that yarn coherency of the product is primarily due to internal, lateral filament entanglement and not to filament wraps.

The continuous-filament yarn may be of any synthetic thermoplastic polymer, e.g., polyamides, polyesters and polyolefins. Nylon filaments are preferred. The filaments may be of round, non-round including lobed and voided or hollow cross-sections. The yarns may be comprised of mixed filaments, e.g., differentially dyeable, different cross-section, different polymers and so forth.

The products are particularly useful in tufted fabrics such as carpets but may also be used in other fabrics where bulky, coherent, normally-twisted yarns are used, e.g., knitted fabrics such as bulky-knit sweaters. The products provide good operability because of their coherency, e.g., they can be tufted on full-size machines operating at 4 yds./min. (3.7 meters/min.).

## EXAMPLE I

A bulky, highly entangled yarn of 6—6 nylon is prepared by feeding three ends of an 865 denier, 6 d.p.f. drawn yarn of round filaments to a jet device similar to that of FIG. 2, except it has only two pairs of opposed jet stream conduits positioned at right angles to each other and to the yarn passageway. One pair of conduits has a diameter of 0.055 inch (1.40 mm.) and the other of 0.028 inch (0.71 mm.). The conduits intersect the passageway at a point where the yarn entrance passageway tapers abruptly outwardly from a diameter of 0.076 inch (1.93 mm.) to an exit passageway diameter of 0.098 inch (2.49 mm.), the latter being 0.625 in. (15.9 mm.) long. The centers of the conduits are 0.625 inch (15.9 mm.) from the exit end of the jet passageway. The total passageway length is 1.125 inches (28.57 mm.). The two passageways are joined by a standard 59° taper.

The feed yarn speed is 203 yd./min. (186 meters/min.) to give an overfeed of 40% based on the windup speed. The yarn is fed into the jet and removed at a 90° angle proceeding directly to a windup device. The yarn forms a U-shaped "rooster tail" bend at the jet exit. The jet device is supplied with steam at 210° C. and a pressure of 110 p.s.i.g. (7.73 kg./cm.$^2$).

The resulting product is highly bulked as a result of a random, three-dimensional filament crimp, typical of a hot-fluid jet bulked yarn, with a high yarn coherency. The yarn is tufted into $\frac{3}{16}$ gauge cut-pile carpets of 26 and 50 oz./yd.$^2$ (0.88 and 1.7 kgs./meter$^2$) weight having a 1-inch (2.54-cm.) pile height. The carpets are dyed in a beck. The tuft definition of the dyed carpets is noted to compare favorably with that of commercial polyester staple cut-pile carpets.

## EXAMPLE II

A bulky, coherent continuous filament yarn is prepared using as the feed yarn two ends of a 1260 denier, 6 d.p.f., 6—6 nylon yarn having round filaments which have been drawn at a draw ratio of 3.63× and which contains 1.1% finish as described in Example III. The apparatus arrangement is of the type shown in FIG. 1. A jet device of the type shown in FIG. 2 is used. The pair of primary jet-stream conduits have a diameter of 0.055 inch (1.40 mm.) and the two pairs of stabilizing jet-stream conduits have a diameter of 0.028 inch (0.71 mm.). The axes of the paired conduits are in a plane perpendicular to the yarn passageway axis with the conduits equally spaced at 60° angles from each other. The yarn entrance passageway in the main jet body is 0.562 inch (14.3 mm.) long to the center of the fluid conduits and has a diameter of 0.076 inch (1.93 mm.). At the point of intersection the yarn passageway tapers out to an exit diameter of 0.098 inch (2.49 mm.). The mid-point of the taper is on the center line of the fluid conduits. The taper is such that the bottom of a $\frac{3}{32}$ inch (2.38 mm.) ball lying in it is 0.539 inch (13.7 mm.) from the outside end of the yarn entrance passageway. The total length of the yarn passageway is 1.12 inches (28.4 mm.). The last $\frac{1}{4}$ inch (6.35 mm.) of the yarn exit passageway has a 7° expanding taper. The yarn entrance in the main jet body is tapered outwardly with a 90° angle to a diameter of 0.197 inch (5.00 mm.). To control the yarn entering the main jet body, attached thereto at the entrance is a flared tube 5.37 inches (13.6 cm.) long having an inside diameter of 0.187 inch (4.75 mm.) at the attaching end and 0.277 inch (7.04 mm.) at its entrance where it is tapered to a diameter of 0.44 inch (11 mm.) with a 90° angle.

The feed yarn is placed on horizontal creels and strung into the preheat chest. The chest is 16 inches (51 cm.) long, 9½ inches (24 cm.) wide and 8 inches (20 cm.) deep. The chest contains two 3½ inches (8.9 cm.) diameter rolls, 10 inches (25.4 cm.) center-to-center, on which the yarn is wound, with 10 wraps. The distance from the bottom roll to the jet device is 15¾ inches (40 cm.). The rolls are heated to 210° C. The yarn speed is 462 y.p.m. (422 meters/min.). The yarn enters axially into the bottom of the jet and is pulled away from the "rooster-tail" at 90° to the jet axis. The jet is supplied with steam at a pressure of 125 p.s.i.g. (8.79 kg./cm.$^2$) at 260° C. The yarn is wound up under nominal tension of 100 grams with a take-up roll speed such that there is a 92% overfeed of the yarn to the jet.

The resulting yarn has 13.2% stabilized bulk, a stabilized bulked denier of 3420, an elastic stretch of 19.2%, and a lateral pull-apart distance as described herein of 1.22 inches (31 mm.) with a standard deviation of 0.23 inch (5.8 mm.). The filaments have a random, curvilinear, three-dimensional crimp of about 8.5 c.p.i. (3.3 cm.). The yarn has a highly uniform appearance of bulk along its length and apparent uniform bulk throughout the filament bundle (freedom from tight spots along the end and across the yarn bundle). Photomicrographs of the yarn show it to be highly entangled through intertwining of filaments and laterally-oriented filament loops and convolutions which develop a continuous web-like structure throughout the yarn filament bundle.

Examination of the yarn shows a filament wrap frequency of less than 0.1 wraps per meter. These wraps encompass less than a third of the filament bundle and cause only a slight node or constriction on one side of the bundle. The wrap frequency is determined by examining at least 20 one-meter lengths of yarn taken at random from a yarn package.

The yarn is tufted into a 30 oz./yd.$^2$ (1.0 kg./meter$^2$) cut-pile carpet with a 1-inch (2.54-cm.) pile height of $\frac{3}{16}$ gauge with a commercial spunbonded polypropylene backing. The carpet is dyed dark green in a beck dyer. The beck reel rotation is reversed every 5 minutes to promote formation of rounded tuft tips. For comparison with Item A above, carpets of the same construction are prepared from Item B, a commercial 3700 denier, 18 d.p.f. 6—6 nylon yarn which has been hot fluid-jet bulked to give an elastic stretch of 45.1% with 12.7±3 c.p.i. having a pull-apart distance of 5.38 inches (13.7 cm.) and Item C a hot fluid-jet bulked 6—6 nylon yarn having a denier of 2420, 6 d.p.f., an elastic stretch of 22.4%±5% and a pull-apart distance of 5.20 inches (13.2 cm.). Both Items B and C contain filaments of a trilobal cross-section.

Comparison of the dyed carpets shows poor tuft definition for Item B which has a matted appearance. Both Items A and C initially have acceptable tuft definition but, after 16,000 cycles in a floor wear-test, Item C has a matted appearance whereas Item A still has clear tuft definition as typically desired for such cut-pile carpets. The floor test is conducted by laying sections of the carpets (generally 12 inches (30 cm.) square or larger) in a busy hallway where traffic cycles (time stepped upon) are measured by a pressure-sensitive pad fastened at the end of the strip and attached to a counter. The counter is activated when the carpet thereon is stepped upon, which is recorded as the number of traffic cycles.

## EXAMPLE III

A bulk, highly coherent 6—6 nylon, for use in the preparation of a shag-type carpet, is prepared using the same apparatus as described in Example II except that the internal jet dimensions are modified to accommodate the heavier denier yarn to give an internal configuration as shown in FIG. 3. This is accomplished by enlarging the diameter of the yarn passageway exit between the 7° tapered exit portion and the cross-jet zone to 0.141 inch (3.58 mm.) to a depth such that a ⅛ inch (3.18 mm.) diameter ball resting in the point where this enlarged diameter tapers to the original exit passageway diameter of 0.098 inch (2.49 mm.) has its center 0.059 inch (1.50 mm.) from the center line of the fluid jet-stream conduits. Three ends of a 1340 denier, nominally 13 d.p.f. yarn are used. The yarn has been drawn 3.71 times and contains filaments of trilobal cross-section having a modification ratio of 1.6. The preheater roll temperature is 70° C. The feed yarn speed is 240 y.p.m. (219 meters/min.) with a take-up speed so as to give 80% overfeed to the jet zone. The feed yarn contains 1.2% by weight of a yarn finish consisting of 70% by weight of the bis(2-ethyl hexoate) ester of polyethylene glycol 200 and 30% Nonisol® 100 (polyglycol fatty acid esters), nonionic emulsifying agent by Alrose Chemical Co., Providence, R.I. The windup tension is about 200 grams. The jet conduits are supplied with steam at 260° C. and 80 p.s.i.g. (5.6 kg./cm.$^2$).

The resulting product has 22.4% stabilized bulk, a stabilized bulked denier of 5898 (under a load of 280±3 grams), elastic stretch of 15.3% (with a 300±3 gram load), and about 8.0 c.p.i. (3.1/cm.) of a random three-dimensional curvilinear crimp with randomly reversing filament twist typical of a hot fluid-jet bulked yarn as described in U.S. Pat. No. 3,186,155 to Breen and Lauterbach. The product has an average pull-apart distance of 0.47 inch (12 mm.) with a standard deviation of 0.12 in. (3.0 mm.). The product has a highly entangled, uniform appearance with substantially no tight spots (marked reductions in yarn bundle diameter). There are numerous crunodal filament loops, both within the yarn bundle and on the surface, in addition to a complexity of other entangling configurations where filaments laterally traverse the interior of the yarn bundle which provides coherency without unduly restricting yarn bulk or volume. Examination for filament wraps as in Example II shows a filament wrap frequency of less than 0.05 wrap.

The product is tufted into a shag carpet construction with no difficulty on a ⅜-gauge tufting machine at 35 oz./yd.$^2$ (1.2 kg./meter$^2$) using a commercial spun-bonded polypropylene backing. The pile height is 1¾ inches (4.4 cm.). The carpet is compared to ones of similar construction prepared from commercially available polyester staple in a single yarn (twisted but not separately heat-set) and a twist-set yarn.

The twist-set polyester carpets are noted to have less resilience (bounce) than the one from yarns of this invention, presumably since the polyester yarns are inhibited by twist. Carpet bulk is judged to be equivalent to the singles polyester product and superior to the twist-set polyester staple product. Pilling and fuzzing performance is equivalent to the twist-set polyester product and superior to the singles item. Texture retention after 16,000 traffic cycles on the floor for the product of this invention is judged to be better than that for the singles yarn item and equivalent to the twist-set staple product.



Thus this invention provides a product meeting commercial cut-pile carpet performance standards without the need for using a twisted-set yarn.

## EXAMPLE IV

This example show the unacceptable carpet bulk (poor economies) and tactile aesthetics of coherent yarns with low filament crimp and elastic stretch which can result from the use of excessive tension on the yarn during the bulking-entangling operation.

A jet of the type described in Example I is used operating with steam at 240° C. and 30 p.s.i.g. (2.1 kg./cm.$^2$). The feed yarn is three ends of 840 denier, 6 d.p.f. 6—6 nylon with round filaments. Yarn is fed to the jet device from a feed roll at 140 yd./min. (128 meters/min.) followed by a take-up roll such that there is 40% overfeed and wound-up using a wind-up tension of 500 gms. The yarn enters and exits the jet device at 90° angles. It contains 1.1% finish as described in Example III. The resulting product has 4% stabilized bulk, a stabilized bulked denier of 3140, an average pull-apart distance of 1.80 inch (4.57 cm.) with a standard deviation of 0.43 in. (1.1 cm.) but has an elastic stretch of only about 6% and only 2.5 c.p.i. of a random three-dimensional curvilinear crimp. The yarn is tufted into a one-inch Saxony-plush carpet. Although the carpet has good tuft definition from the high coherency, the low bulk (elastic stretch and c.p.i.) allows the tufts to lean over, thus producing an unacceptable Saxony-type carpet.

## EXAMPLE V

This example demonstrates the preparation of a product of this invention from a crimped but noncoherent yarn.

The feed yarn is a 1260 denier, nominally 6 d.p.f., round filament cross-section, about 3.66 times drawn 6—6 nylon or poly(hexamethylene adipamide) yarn which has been gear-crimped at 190° C. The feed yarn contains 1.15% by weight of the same finish as in Example III and is passed through a folded wet sponge prior to entering the jet, which moistens it.

The jet device is the type used in Example I. It is supplied with air at ambient temperature (~25° C.) under 90 p.s.i.g. (6.3 kg./cm.$^2$) pressure.

Two ends of the yarn are supplied to the jet from a feed roll at a speed of 247 yd./min. (226 meters/min.) to give a 23% overfeed as controlled by the wind-up speed after the jet treatment. The yarn enters and leaves the jet device at an angle of 90° to the yarn passageway.

The resulting product has 24.6% stabilized bulk, stabilized bulked yarn denier of 3140, an elastic stretch of 15.1%, 8.2 c.p.i. (3.2 crimps/cm.) of a sine wave-like crimp and an average pull-apart distance of 0.95 inch (2.41 cm.) with a standard deviation of 0.27 inch (0.69 cm.).

In experiments under a similar range of conditions attempts are made to produce a product of this invention using as the feed yarn a commercial, hot-fluid bulked, continuous filament, 6—6 nylon carpet yarn containing filaments of trilobal cross-section similar to that of Item B, Example II. The filaments have random, three-dimensional, curvilinear crimp and are only moderately entangled as a result of the crimping treatment. However, the resulting products had insufficient entanglement and coherency to meet the requirements of the invention. It is speculated that the moderate entanglement of the feed yarn prevented the development of additional entanglement of the proper type to give the desired product.

We claim:

1. A heavy denier crimped yarn of at least 50 crimped continuous thermoplastic filaments interentangled in a structure characterized by laterally-oriented filament loops which penetrate within said structure and bind other filaments in place in the yarn; the filaments having at least four crimps per inch of significant size which provide an elastic stretch of 8% to 40% when the yarn is subjected to a load of 0.1 gram per denier, with a filament interentanglement which provides at least 5% of stabilized yarn bulk when under a load of 0.1 gram per denier; the bulk being stabilized by filament interentanglement which provides less than 3.5 inches mean separation distance of filament groups under a one-pound load in the lateral pull-apart test, with a standard deviation of individual determinations of less than 0.5 times the mean separation distance for ten determinations at random intervals along the yarn; and the yarn being substantially free from any twist or external filament wraps sufficient to have appreciable effect on values obtained in said lateral pull-apart test.

2. A yarn as defined in claim 1 which has a stabilized bulked yarn denier of 1000 to 7000, determined with the yarn under a tension of 0.1 gram per denier.

3. A yarn as defined in claim 2 wherein the yarn filaments are 5 to 20 denier per filament.

4. A yarn as defined in claim 1 composed of nylon filaments.

5. A yarn as defined in claim 1 wherein the filaments



have about 8 to 16 crimps per inch of persistent, random, three-dimensional, curvilinear configuration.

6. A yarn as defined in claim 1 wherein said elastic stretch of the yarn is 13% to 30%.

7. A yarn as defined in claim 1 wherein said percent stabilized bulk is 15% to 30%.

8. A yarn as defined in claim 1 wherein said mean separation distance of filament groups in the lateral pull-apart test is 0.25 to 2.0 inches.

9. A yarn as defined in claim 1 wherein said standard deviation of individual determinations of separation distance is less than 0.4 times the mean separation distance of filament groups in the lateral pull-apart test.

10. A yarn as defined in claim 1 wherein the yarn is substantially free from twist, and has less than one filament wrap per yard of yarn which winds around the filament bundle and causes a decrease in bundle diameter.


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