POLYPROPYLENE BULKED YARN

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2 Claims. (Cl. 57—140)

This application is a continuation-in-part of application Serial No. 130,493 filed Aug. 10, 1961, now abandoned.

This invention relates to a textile process and product and, more particularly, to a process of imparting crimp to continuous polypropylene filaments to produce a bulked multifilament yarn and to the bulked multifilament yarn produced thereby.

Breen, U.S. Patent 2,783,609, discloses a process of exposing a multifilament continuous yarn to a rapidly moving turbulent stream to induce a multitude of crumnodal filament loops at random intervals along the individual filaments. Such loops and the snarls of entangled loops resulting from this treatment increase the bulk of the continuous filament yarns considerably and fabrics made of such yarns have improved cover, bulk, handle, and the like.

U.S. Patent application Ser. No. 698,103, filed November 22, 1957, in the names of Breen and Lauterbach, assigned to the assignee of the instant application, discloses a new process which gives multifilament continuous yarn having a bulkiness greater than staple yarn spun from comparable fibers. Such bulked continuous filament yarns resemble spun staple yarns in desirable lightness, covering effectiveness and warmth-giving bulk but retain the characteristic continuous filament freedom from loose ends, fuzziness, and pilling. The bulkiness of the yarn results from the persistent crimp imparted to the individual filaments making up the yarn. The process comprises feeding continuous filament yarn into a turbulent plasticizing stream of a compressible fluid such as steam, having a temperature above the second order of transition temperature of the polymer of which the filaments are made, at a feed rate greater than the yarn take-up speed. The individual filaments of the yarn are supported by the stream of fluid, i.e., under substantially zero tension, and are separated from each other and crimped individually by whipping about in the turbulent plasticizing region of the stream of compressible fluid and then rapidly cooled to set the crimp while the filaments are still maintained at low tension. The individual filaments are set in a series of crimps having a random, three-dimensional, non-helical, extensible configuration.

When a yarn composed of ordinary continuous polypropylene filaments is processed as taught in application Ser. No. 698,103, well crimped filaments are obtained. However, such filaments are not as crimped as, for example, polyamide filaments and for certain purposes such as for use in loop pile carpets and the like, yarn of filaments having an improved crimp is desirable.

An object of the present invention is to provide a process which will give a bulked continuous filament polypropylene yarn more comparable to bulked continuous filament polyamide yarns, suitable for use in carpets and the like. A further object is to provide an improved bulked continuous filament polypropylene yarn particularly adapted for loop pile carpeting. Other objects will be apparent from the description of the invention given hereinafter.

FIGURE 1 is an illustration of the individual filaments of the invention. Points c show what appear to be angular crimp form. This is intended to represent a region where the filament path is in the general direction perpendicular to the plane of the illustration causing apparent distortion of the curvilinear form.

The above statements apply similarly to the filaments comprising the yarn illustrated in FIGURE 2.

FIGURE 2 shows a multifilament yarn composed of filaments of FIGURE 1 and it can be seen that the filaments are substantially interentangled within the yarn bundle.

One object of this invention has been attained by an improved bulked yarn of crystalline polypropylene filaments having an exceptional degree of compressional resilience, crimp and covering power, the filaments being characterized by:

1. gamma orientation,
2. an orientation angle of 10 to 60°,
3. alternate "S" and "Z" twist sections throughout the length,
4. a random number of turns between twist reversals,
5. a random continuously varying angle of twist along the filaments,
6. a random number of twist reversals per inch,
7. at least one "Z" turn and at least one "S" turn per inch with each turn having a twist angle averaging at least 5°,
8. and a random, persistent three-dimensional, non-helical, curvilinear crimped configuration continuously along the length, said filaments being substantially free from stable crumnodal loops.

Preferred products of this invention are characterized by more than 8 crimps per inch and a compressional recovery of more than 75%.

A process for producing the bulked yarn of the invention having a high degree of crimp, compressional resilience and high covering power comprises the steps of:

1. extruding a plurality of filaments of crystalline substantially isotactic polypropylene, having a melt index of from 0.1 to 200, under conditions such that the filaments have gamma orientation after drawing,
2. quenching the filaments to produce asymmetrical cooling and internal stresses, thereby providing a potential helical crimp of from 2 to 20 crimps per inch,
3. and drawing the quenched filaments less than 2.5 X at a temperature and velocity of draw such that the filament shrinkage is less than 20% of its drawn length in boiling water, and the filament has an orientation angle of from 10 to 60°. At this point of the process the individual polypropylene filaments of the yarn are characterized by (a) gamma orientation, (b) an orientation angle of 10° to 60°, (c) a potential shrinkage of 0% to 20% and (d) a potential helical crimp of 2 to 20 crimps per inch. The filaments are then subjected to a plasticizing stream of a compressible fluid having a temperature above the second order transition temperature of the polypropylene. In this stream, the individual filaments while in a plastic state and under substantially zero tension, are separated from each other and crimped individually and the crimp is set.
Preferably the drawing is done so that the potential shrinkage is at least 4%; the compressible fluid has a temperature of from 100 to 200° C. and more preferably steam is used as the compressible fluid.

It has been found that the characteristics of the polypropylene filament forming the yarn which is to be processed, have a surprisingly great influence on the bulked yarn resulting from the process. The commercially available polypropylene filaments which have "normal" orientation as distinguished from polypropylene filaments having gamma orientation, give a bulked yarn after processing that, even though bulked by permanent crimping of the configuration described above, appears to be somewhat lacking in covering power and lean rather than giving the illusion of great bulk. This is particularly noticeable when the yarn is made up into carpeting.

By contrast to the yarn obtained by crimping polypropylene filaments of "normal" orientation, the yarn obtained in the instant process by crimping polypropylene filaments having gamma orientation and the characteristics as above specified, is sharply distinguished in appearance and when made up into carpeting, appears to have much greater covering power and an illusion of far greater thickness. The crimped polypropylene yarn of this invention tends to have more crimps per inch and, in carpets, better resists matting when subjected to wear-tests, than heretofore made crimped polypropylene yarns made into carpeting of similar structure. The difference between carpeting made of the polypropylene yarns of this invention and prior polypropylene yarns in appearance is very obvious at a glance, both before and after wear-test, with the advantage manifestly in favor of the yarns of this invention.

It will be apparent from the above that critical to this invention is the polypropylene yarn subjected to the crimping process. According to this invention, the individual polypropylene filaments to be crimped should have four characteristics, namely, gamma orientation rather than "normal" orientation, an orientation angle of 10° to 60°, a potential shrinkage of 0% to 20%, and a potential helical crimp of 2 to 20 crimps per inch. For purposes of clarity and definiteness, the terms used in characterizing these polypropylene filaments are defined below. They are used throughout the specification and claims as defined.

The term "orientation angle" is a parameter which represents the alignment of molecular axes of the material forming a filament with respect to the filament axis. The orientation angle is indicated by the azimuthal extent of the intensity of the (040) X-ray diffraction arc at 2θ=16.7°. These indices are used according to G. Natta et al., Atti accad. nazl. Lincel, Rend. Classe si, fis. mat. e nat. [8] 21,363 (1956). The orientation angles are measured according to the technique of B. G. Ingersoll, Journal of Applied Physics, 17,924 (1946), on the instrument described by J. E. Owens and W. O. Statton, Acta Crystallographica, 10, 560 (1957). This angle using the (040) arc is a measure of crystallite orientation with respect to the filament axis (C axis).

The term "gamma" orientation denotes the unusual orientation or condition of material in a filament which is detected by X-ray diffraction techniques by a diffraction pattern in which the (110) diffraction arc at 2θ=14.0° exhibits intensity maxima at an azimuthal angle greater than 50° from the equator. The intensity maxima has a ratio greater than 0.6 when compared to the intensity maxima of the (022, 122) X-ray diffraction arc at 2θ=28.6° (I1/I2). This ratio is determined from a radial photometer trace obtained 10° from the meridian on the Leeds and Northrup Knorr-Aller Model 6700-P1 microphotometer with 0.01 mm. slit width and 1.5 mm. slit length. The peak intensities of the maxima are determined above the background scattering in the following manner: For the peak at 2θ=14.0° a straight line is drawn on the photometer trace connecting the intensity values at 2θ=9.3° and 2θ=11.3°; this sloping straight line is extended under the peak and the intensity value of this line at the peak position is used as the background value and subtracted from the peak value to give a quantity, L. For the peak at 2θ=28.6° a sloping straight line is drawn connecting the intensity values at 2θ=25.0° and 31.2°; the value on this line at the peak position is subtracted from the peak value to give a quantity, L.

Oriented filaments having a gamma intensity (I1/I2) of less than 0.6 are designated as having "normal" orientation hereinafter. Oriented filaments having a gamma intensity ratio greater than 1.0 are preferred for use in this invention.

The term "potential shrinkage" denotes, in percentage of the original length, the amount an uncrimped filament shrinks when placed in unrestrained condition in boiling water for two minutes. Upon removal from boiling water, the filament is placed under just sufficient tension to straighten it and then its length is measured.

The term "potential helical crimp" denotes, in crimps per inch, the amount an uncrimped filament is cramped when placed in unrestrained condition in boiling water for two minutes. This crimp developed in boiling water is helical in configuration and quite distinct from the random, non-helical crimp resulting from the instant process. By "crimp per inch" is meant the number of complete turns per inch of cramped length of a filament.

Preparation of polypropylene filaments

Filaments having the requisite characteristics for use in the present process can be made from any high molecular weight polypropylene characterized by a melt index (ASTM Standards, 1958, D-1238-57T, part 9, page 38) of 0.1 to 200. It is preferred to use a polymer showing a stiffness of greater than 120,000 pounds per square inch when prepared in test bars according to ASTM test D-747.

The extrusion of the filaments must be under such conditions as to afford gamma orientation. The spinning variables are adjusted to regulate the viscosity of the polymer melt as extruded through the spinneret orifices, and the viscosity of the fiber as it changes from the molten state to the solid state. In general, the surface temperature of the spinneret should be maintained close to the minimum temperature needed to afford good spinning continuity. The absolute value of the spinneret temperature, as will be recognized by those skilled in the art, is dependent upon the temperature of the polymer melt, the dimensions of the orifices in the spinneret, the throughput of polymer, the location and intensity of the quench, and the advancing velocity of the extruded filaments. Since the temperature of the polymer melt is usually selected to provide a certain melt viscosity, it will be appreciated that polymers with different melt indices will require different temperatures.

In the spinning process, the freshly-extruded filaments are cooled by a stream of a quenching gas, normally air, directed against each filament within about three inches and preferably within one inch of the spinneret face at an angle between 45° below and 45° above the horizontal. As is well understood in the art (see Morrell, U.S. Patent 2,730,758 or British Patent 807,248, for example), the quenching gas is directed at the filaments as they are extruded in a manner that effects non-uniform cooling of the filaments with the result that the filaments possess potential helical crimp, particularly if they are also drawn to some extent. The quenching gas may have a velocity of between 50 and 1500 feet per minute but preferably 250 to 1000 feet per minute at the point of contact with the filaments.

It is important that the filament should have an orientation angle within the range of 10° to 60° and the stretch ratio (i.e., velocity of solidified threadline/calcu-
lated velocity of the molten polymer through the spinneret) and the quench, as well as any drawing of the solidified filaments, should be controlled to give an orientation angle within that range. The necessary orientation may be obtained without a draw but in no case should the filaments be drawn under conditions that give over 20% potential shrinkage. A potential shrinkage of at least 25% is preferred which requires some drawing of the filaments; further, it is usually necessary to draw to some extent to obtain the requisite potential crimp.

The drawing step may be carried out in any convenient manner using techniques well known in the art such as the use of a heated pin, a heated plate, heated liquids, coils of wire, or the like. These are not critical but the draw ratio (i.e., drawn length/undrawn length) should be kept below about 2.5 X in order to retain the gamma orientation in the fiber.

The bulking process

The process of imparting a persistent crimp to the polypropylene filaments, i.e., the process of bulking the yarn composed of a plurality of the polypropylene filaments, is similar to that described in said U.S. application Serial No. 698,103 in which various arrangements of apparatus for carrying out the process are shown.

A stream of compressible fluid at a temperature above the second order transition temperature of the polymer of which the filaments are made and, preferably, at least about 100° C, is vigorously jetted to form a turbulent plasticizing region. The yarn to be treated is positively fed at a rate greater than the yarn take-up speed into the fluid plasticizing stream so that the yarn is supported by and individual filaments are separated from each other and crimped individually by whipping about in the hot turbulent plasticizing and bulking region, and rapidly cooled while being maintained at low tension to set the crimped configuration.

The process elements such as temperature, pressure, fluid flow, yarn speed tension and windup speed are adjusted to give a final yarn denier (measured in relaxed form after hot-wet relaxation, i.e., after "boil-off") at least 30% greater than the feed yarn denier. The crimped filaments are withdrawn from the plasticizing zone by the fluid exhaust and the take-up rolls. The filaments pass through a reheating zone or after the take-up rolls to prevent further plastic flow and insure retention of the crimp while maintaining the yarn in a substantially relaxed tensionless condition. After cooling, tension may be applied to the yarn to remove fiber loops, eliminate packing of filaments and improve the bulking characteristics of the yarn.

Assuming a yarn of polypropylene filaments of the particular characteristics as herein taught is used as the starting material, the bulked yarn resulting from this process is composed of crimped individual filaments having gamma orientation and an orientation angle of from 10° to 60°, probably somewhat less than a 60° orientation angle as the bulking process tends to lower the orientation angle, particularly if it is in the upper range in the starting yarn, and each filament is formed with alternate "S" and "Z" twist sections throughout their length, a random number of turns between twist reversals, a random continuously varying angle of twist along the filament, a random number of twist reversals per inch, at least one "S" turn and at least one "Z" turn per inch with each turn having a twist angle averaging at least 5° in a random, presistent, three-dimensional, non-helical, curvilinear crimped configuration continuously along its length and substantially free from stable crumpled loops.

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

The temperature of the fluid medium must be regulated so that the yarn temperature does not reach the melting point of the filaments. The temperature of the turbulent fluid may be above the melting point of the filaments but in this case the yarn speed must be great enough so that melting does not occur. Because of the great turbulence and the high heat, the individual filaments are heated rapidly.

To achieve maximum bulking or crimping it is essential that the tension of the yarn subject to the turbulent fluid medium be maintained below about 0.1 gm./denier. Preferably, yarn tension during the bulking is maintained between about 0.0001 and about 0.01 gm./denier. For the most efficient bulking action at the highest degrees of bulk and highest throughput of yarn, the tension of the yarn should be maintained between about 0.0005 and about 0.005 gm./denier. This low tension in the yarn is preferably regulated by controlling the yarn take-up rate vs. yarn take-up rate so that the bulked yarn forms a shallow eatenary between the jet and the downstream guide. The tension can also be governed by the degree of forwarding or braking action of the fluid plasticizing medium.

Yarn feed speed can be varied over a considerable range depending on the material, temperature, denier, degree of bulking, tension, and other variables. For economic reasons (productivity/position) the feed rate should be at least 30 y.p.m. although slower speeds may be used for specific items or special effect. Feed rates can run as high as 1000 y.p.m. or even higher. Preferred feed rates are in the range of 100 to 800 y.p.m.

The temperature of the heating fluid must be high enough so that either alone or in combination with some auxiliary plasticizing component, e.g., water, acetone, or other solvent, it will soften or plasticize the yarn passing through the heating area. The optimum temperature, of course, varies depending upon the yarn being treated, i.e., the denier or yarn size, the rate of throughput, the degree of turbulence and/or pressure of the treating fluid, and the degree of crimping desired. The temperature can range as high as 370° C or more and a preferred range is 100° C to 200° C. The controlling factors are the characteristics of the polypropylene filaments being treated and the temperature actually reached by the filaments during treatment. The yarn temperature during the crimping operation should exceed the second order transition temperature to insure permanent crimp. The true upper limit, of course, is the temperature at which objectionable melting and/or chemical degradation of a given yarn takes place.

There are a number of means and apparatus whereby a turbulent stream of fluid can be produced. Suitable jets or devices for treating a yarn with a turbulent plasticizing fluid to achieve the improvements of this invention are described in Breen U.S. Patents 2,783,609; 2,852,906; and 2,869,967, and U.S. application Ser. No. 698,103.

It is necessary to cool the crimped yarns after treatment in the turbulent plasticizing fluid and prior to any further operation that imposes tension on the yarn bundle. This quenching, cooling, or freezing operation is necessary to lock in the three-dimensional, random, curvilinear configuration imposed on the various filamentary elements by the hot turbulent fluid.

The yarn overflow should be adjusted so that the tension in the processing zone is in the range indicated above. The overflow rate can be as high as 250%, or higher but for most yarns this value is from 15% to 100%, preferably above 30%.

The feed pressure of the hot plasticizing fluid will depend on the degree of turbulence desired, feed speed, yarn denier, material being processed, design of jet, and the like. Gauge pressures in the range of 20 p.s.i. to 200 p.s.i. or more are useful while the preferred range is from 40-100 p.s.i. Normally, economics will dictate that the optimum pressure is the lowest that still gives the desired degree of crimping.

It is preferred that the feed yarn contain little or no twist. The twist level should be below 2.0 turns per inch.
and preferably below 1.0 turn per inch. Yarns of higher twist levels can obviously be processed; however, the tendency is for the formation of stable loops and filaments intertwanging at the expense of bulk and extensibility of the yarn bundle—thus the yarn bundles become increasingly compact as the twist level rises.

The hot bulked yarn can be delivered from the jet onto a foraminous surface to remove the filaments from the plasticizing medium while keeping the filaments in a tensionless state. The foraminous surface can be any perforated surface in the form of a metal screen, parallel with a belt, a hollow roll or disc, or the nip of two such belts or rolls moving in such direction to remove the yarn from the turbulent region. The crimp developed should be set before any appreciable tension is supplied on take-up from the foraminous surface. This setting by cooling can be obtained by adjusting the length and/or time of passage on the foraminous surface after leaving the turbulent region or an auxiliary cooling means may be employed such as a current of air or the like.

The following multiple example illustrates a specific embodiment of the invention, showing preparation of the starting yarn, the bulkling process of this invention, and the use of the bulked yarn in carpets along with certain controls.

**EXAMPLE**

**Preparation of the starting yarn**

A crystalline polypropylene of melt index 10 is made by degrading 0.7 melt index propylene ("Profax") made by Hercules Powder Co., Wilmington, Delaware) by heating in an extruder at 230° C. in the presence of t-butyl hydroperoxide and then adding 0.1% 4,4'-butylidene bis(6-t-butyl m-cresol) as a stabilizer.

The above polymer is extruded as a melt at 190° C. through a spinneret having a surface temperature of 170° C., using apparatus as shown in FIGS. 1 and 2 of Herman application Ser. No. 108,001 filed May 5, 1961, wherein the solidified yarn is advanced over feed rolls both rotating at 100 yards per minute (y.p.m.) and then over a one-inch diameter pin heated to 110° C. and located below the feed rolls rotating at 150 y.p.m. The drawn yarn is collected on a package. The spinneret contains ten holes of a modified Y cross section which gives a tribrachiate cross-section filament. The extruded filaments are quenched by room temperature air directed across them as shown in FIG. 2 of Ser. No. 108,001 at a velocity of about 675 feet per minute. The quenching apparatus as shown in FIGS. 2 and 2x of Ser. No. 108,001 comprises a ¾-inch outside diameter tube containing a plurality of ½-inch diameter holes adapted to direct air against the wall of a cylindrical chamber in which the tube is mounted, except for the wall facing the threadline of extruded filaments. On the wall facing the threadline, the chamber is provided with a 200-mesh screen. Air forced through the tube strikes the solid walls of the chamber and is deflected therefrom through the screen wall facing the threadline against the threadline.

The salient processing factors and physical properties of the resulting yarn are shown in Table I as Item 1.

The Item 1 yarn fully qualifies as the starting yarn in the present process. The tenacity and elongation is given in Table I and it will be noted this yarn has relatively low tenacity and high elongation, characteristics of the yarn suitable for use in the instant bulking process.

For Item 2 yarn, Table I, a polypropylene of melt index 12 is used. This polymer is similar to that used for Item 1 except that it has been extracted with boiling n-heptane. A spinneret containing 23 Y-shaped orifices is used and the polymer is extruded as a melt at 230° C.

The threadline is quenched with room temperature air at a velocity of about 200 feet per minute from a porous metal band located in a slot 1.5 inches high on the inside of a cylindrical chamber (inside diameter 2 inches) placed concentrically with respect to the threadline with the top of the quenching chamber 2 inches below the spinneret rather than level with the spinneret as in Item 1. The yarn was drawn in the same general manner as in Item 1 but at a ratio of 4.8 X at 118° and then 1.5 X in 55° C. water.

Item 2 yarn does not qualify as a starting yarn in the present process because the filaments have no potential crimp nor are they gamma oriented. The quench is quite mild and the yarn has been drawn too much to preserve the gamma orientation. Note this Item 2 yarn is also quite different from Item 1 yarn in that it has, relatively, high tenacity and low elongation.

The Item 3 yarn is made from 0.7 melt index polypropylene (not degraded) following the procedure used for preparing the Item 1 yarn except that a spinneret containing 40 round orifices of 0.009 inch diameter is used. The polymer is extruded as a melt at 253° C. and advanced over the feed rolls at 60 y.p.m., the quenching conditions being substantially those used with Item 1. The yarn was drawn 1.8 X at 130° C.

This Item 3 yarn fully qualifies as the starting yarn in the recent process. Like Item 1 yarn, it is a relatively low tenacity/high elongation yarn.

The Item 4 yarn is made from the same polypropylene of 0.7 melt index and uses the same spinneret as in Item 3. However, an annealing heater surrounds the threadline about ½ inch below the spinneret and the circular quench chamber of Item 2 is located about 6 inches below the spinneret. The annealing heater comprises a coil of resistance wire around a metal cylinder (2 inches high) with an inside diameter of 2.75 inches. The surface of the cylinder facing the filaments is kept at about 500° C. The polymer melt is extruded at 300° C. and the quench is quite mild as shown in Table I.

This Item 4 yarn is not suitable as the starting yarn in the present process because it has no potential crimp nor does it have gamma orientation. The yarn was drawn at too high a ratio and the quench was too mild.

The Item 5 yarn is also made from 0.7 melt index polypropylene and the same spinneret is used as in Item 3. However, the annealing heater and quench chamber of Item 2 are used with the top of the quench chamber about 6 inches below the spinneret. The polymer melt is extruded at 300° C. The yarn was drawn 2.2 X in water at about 3° C.

As shown in Table I, this Item 5 yarn does not qualify as the starting yarn in the present process because the 30% shrinkage is appreciably above the top limit of 20% for shrinkage. Despite the mild quench, the yarn did have a high potential crimp due to drawing at very low temperature. But, as a result of this low temperature drawing, the potential shrinkage was too high.

The Item 6 yarn is also made from the 0.7 melt index polypropylene and the same spinneret is used as in Item 3. The cylindrical quench chamber of Item 2 is used with the top of the chamber level with the spinneret. The polymer melt is extruded at 300° C. and the yarn is not drawn at all.

This Item 6 yarn has no potential crimp despite the intense quench and does not qualify as a starting yarn for use in the bulking process of this invention. This illustrates that the combination of an intense quench plus some drawing is usually necessary to get a potential crimp.

From the various yarns discussed above, it will be observed that an intense quench combined with a low ratio draw at a moderately elevated temperature is conducive to giving a yarn having the requisite characteristics for use as the starting or feed yarn in the instant bulking process. The filaments in the yarns of Items 1 and 2 are tribrachiate in cross section while the filaments in the other yarns are round. The filaments of tribrachiate cross sections have certain advantages in carpet yarns, the particular cross section has no bearing on the present invention.
### TABLE I

<table>
<thead>
<tr>
<th>Item</th>
<th>Spinnert Temp., °C</th>
<th>Feed Roll Temp. (p.p.m.)</th>
<th>Air Quench Volume, c.f.m.</th>
<th>Draw Ratio</th>
<th>Draw Temp., °C</th>
<th>Crimp per Inch</th>
<th>Ten/E</th>
<th>Shrinkage, percent</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>170</td>
<td>190</td>
<td>18.0</td>
<td>4.8</td>
<td>1.8</td>
<td>8</td>
<td>1.4/192</td>
<td>10 Gamma</td>
</tr>
<tr>
<td>2</td>
<td>320</td>
<td>79</td>
<td>4.8-7.1</td>
<td>110-200</td>
<td>3.5</td>
<td>0</td>
<td>6.8/40</td>
<td>2.5 Normal</td>
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<td>3</td>
<td>215</td>
<td>65</td>
<td>2.2-3.2</td>
<td>70-100</td>
<td>0.5</td>
<td>8</td>
<td>2.2/200</td>
<td>5 Gamma</td>
</tr>
<tr>
<td>4</td>
<td>272</td>
<td>120</td>
<td>4.8-2.2</td>
<td>110-200</td>
<td>2</td>
<td>15</td>
<td>4.7/117</td>
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<tr>
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<td>250</td>
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<td>1</td>
<td>15</td>
<td>2.2/205</td>
<td>Gamma</td>
</tr>
<tr>
<td>6</td>
<td>260-270</td>
<td>159</td>
<td>75</td>
<td>28.4</td>
<td>1</td>
<td>2</td>
<td>1.6/200</td>
<td>Gamma</td>
</tr>
</tbody>
</table>

1 Properties measured after year "ball-off."
2 Ten/E = Tenacity/elongation.
3 Water.
4 No draw.

### Preparing the Yarns

The spun yarns are then fed through a jet as shown in Fig. 8 of Breen U.S. Patent 2,852,906 to which steam under pressure is supplied. The jet is modified by the addition of a preheater tube of about 30 inches length attached to the yarn entrance of the jet to catch the backlash of steam from the jet and use in preheating the yarn before it gets to the jet. Its function is to save heat and has little effect on processibility.

Each of the yarns Items 1 to 6 are plied to give a yarn having a total of about 1,000 denier. Each 1,000 denier yarn is then passed through the jet and allowed to recover 24 hours at room temperature. The height of the plug is then measured (to the nearest 1/16 of an inch) and noted as the recovered height. The compression recovery equals

\[
\frac{\text{recovered height}}{\text{initial height}} \times 100
\]

### Preparing Carpets

The bulked yarns thus prepared are plied to 3,900 denier 3-ply yarn (twisted 2 Z in the singles and 1 S in the ply). Tufted, loop pile carpets of the same construction are made from all items. The gauge (needle spacing) of the tufting machine is 3/16-inch, the pile height is 3/16-inch and the stitches per inch are varied to yield a weight of 24 ounces per square yard. All carpets are boiled off before testing.

The wearing quality of the carpets is determined by measuring the thickness with an Ames gauge from which the spring has been removed and appropriate weight supplied to exert a pressure of 0.321 p.s.i. on the foot. Strips of carpet are then submitted to a wear-testing by traffic cycles in a corridor. Each time a person walks across the strip of carpet being tested is a "traffic cycle." The original thickness and the thickness retention (expressed in the percent of the original thickness) of boiled-off samples are given in Table I. The denier per filament of the bulked yarn after boil-off is given in Table II.

A consideration of Table II shows that Items 1 and 3, specific yarns according to the present invention, give both bulked yarns and carpets distinct from that of the control yarns characterized in Table II. The filaments of the bulked yarn average higher in the number of crimps per inch and the compressional recovery is appreciably higher. While the thickness of the original carpet is not necessarily greater, the percent of the original thickness of the carpet retained after 32,000 traffic cycles is high, an indication of resistance to matting and good wearing qualities.

Although the data in Table II does show trends of differences between Items 1 and 3, yarns of the invention, as against Items 2, 4, and 6 which are controls, it by no means brings out the striking difference in appearance of carpets made from these yarns. By comparison of samples of unshed carpet, the high covering power and illusion of greater bulk of samples made from the invention yarns is quite obvious; the samples from the control yarns appear lean and it is easier to see the carpet backing when the pile is pushed sideways with the finger. Samples of carpet after wear-test show even more striking practical differences. The samples made from the invention yarns, aside from being darker due to some soiling during the wear-test, actually are not appreciably different from the samples of unused carpet. By contrast, the samples made from the control yarn are quite different in appearance after the wear-test, having a very matted
and compressed appearance with the individual tufts readily discernible, what can best be described as a very "worn" look.

Table II does not report anything on the Item 5 yarn of Table I. This yarn was bulked at a steam pressure of 50 pounds per square inch with a 60% overfeed and a carpet made from the yarn similar to the carpets made from the other yarns. The carpet was certainly no better than the carpet samples made from the other control yarns and much inferior to the carpets made from the yarns of the invention.

<table>
<thead>
<tr>
<th>Item</th>
<th>Processing Conditions</th>
<th>Bulked Yarn Filament Properties</th>
<th>Carpet Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steam Pressure</td>
<td>Percent Overfeed</td>
<td>Crimps per Inch</td>
</tr>
<tr>
<td>1....</td>
<td>17.5</td>
<td>59</td>
<td>10-15</td>
</tr>
<tr>
<td>2....</td>
<td>18</td>
<td>60</td>
<td>8</td>
</tr>
<tr>
<td>3....</td>
<td>20.7</td>
<td>60</td>
<td>8-12</td>
</tr>
<tr>
<td>4....</td>
<td>23.4</td>
<td>60</td>
<td>5-8</td>
</tr>
<tr>
<td>5....</td>
<td>15.0</td>
<td>80</td>
<td>5-8</td>
</tr>
</tbody>
</table>

1 D.p.f. = denier per filament.  
2 Round cross section; others trilobate cross section.

It will be understood that the foregoing example is merely illustrative and that the invention broadly comprises the process of imparting a persistent crimp to polypropylene filaments or, alternatively expressed, bulking yarns of such filaments, by feeding polypropylene filaments characterized by (a) gamma orientation, (b) an orientation angle of 10° to 60°, (c) a potential shrinkage of 0% to 20%, and (d) a potential helical crimp of 2 to 20 crimps per inch, to a plasticizing stream of a compressible fluid having a temperature above the second order transition temperature of the polypropylene, in which stream the individual filaments, while in a plastic state and under substantially 0 tension, are separated from each other and crimped individually while whipping about in said stream, the crimp having a random, three-dimensional, non-helical, extensible configuration, and setting the crimp thereby imparted to said filaments. The invention also comprises the novel bulked yarns resulting from this process.

The actual mechanical steps and conditions of the bulking process can be varied widely and the optimum specific conditions to obtain the maximum bulk will vary with each different type of feed yarn. The stream of compressible fluid must have a temperature above the second order transition temperature of the polypropylene forming the filaments and it is preferably above 100° C. Steam is the preferred compressible fluid. Overfeed of the yarn is essential as the filaments must be relaxed, i.e., under substantially 0 tension, in order that the filaments may be crimped while being whipped about in the stream of compressible fluid. Preferably, an overfeed of 30% is used. As previously mentioned, the hot bulked yarn can be delivered from the steam jet in different ways, the specific manner of doing this not being a critical part of this invention. Likewise, the crimp in the yarn can be set in different ways either with or without some auxiliary cooling means.

A particular advantage of the present invention is that it provides a process of obtaining bulked polypropylene yarn of obviously superior properties for use in carpets. However, the yarn is likewise adapted for use generally where a crimped yarn is desirable.

As many apparently different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the appended claims.

The invention claimed is:

1. An improved bulked yarn of crystalline polypropylene filaments having an exceptional degree of compressional resilience, crimp and covering power, the filaments being characterized by
   (a) gamma orientation,
   (b) an orientation angle of 10 to 60°,
   (c) alternate "S" and "Z" twist sections throughout the length,
   (d) a random number of turns between twist reversals,
   (e) a random continuously varying angle of twist along the filaments,
   (f) a random number of twist reversals per inch,
   (g) at least one "Z" turn and at least one "S" turn per inch with each turn having a twist angle averaging at least 5°,
   (h) and a random, persistent three-dimensional, non-helical, curvilinear crimped configuration continuously along the length, said filaments being substantially free from stable crumidal loops.

2. The product of claim 1 characterized by more than 8 crimps per inch and a compressional recovery of more than 75%.

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