ABSTRACT: A roving of entangled and self-bonded fine fibers of polypropylene may be formed by a melt blown roving technique which comprises extruding the polypropylene through a die having the die openings in a circle into a gas stream to attenuate the extruded polypropylene into fibers and collecting the fibers as a tow. The roving or tow of polypropylene fibers is an aggregation of fiber loops which is essentially cylindrical in shape, made from essentially continuous fibers which are entangled and bonded to each other. The roving or tow may be cut as filters for cigarettes.
CIGARETTE FILTER FROM POLYPROPYLENE FIBERS

BACKGROUND OF THE INVENTION

The present invention is directed to a nonwoven roving of polypropylene fibers which may be useful as a filtering material especially as filters for cigarettes. The cigarette filter comprises a roving of entangled fine fibers of polypropylene having an average bulk density between 0.05 and 0.20 g./cc. A roving of the polypropylene fibers may be produced which need not be wrapped with paper to provide the proper circumference as a cigarette filter but may be cut and only wrapped with the outer cigarette paper for forming a filter cigarette.

In considering some of the processes of the prior art which disclose the formation of a cylindrical tow of fibers, the following U.S. patents have been considered: U.S. Nos. 2,886,877; 3,023,075; 3,148,101 and 3,232,805.

SUMMARY OF THE INVENTION

The present invention is directed to a roving of fine fibers which are entangled and self-bonded and made up of fiber loops which form an essentially cylindrical tow. The fibers in the roving are essentially continuous fibers looped back and forth from a point on a short radius or near the center of the cylindrical tow to a point on a longer radius or near the outer surface of the cylindrical tow in a fairly uniform manner. The fibers in the roving have a size between approximately 2 and 40 microns. The cylindrical roving has fibers which are preferably self-bonded and have a smooth skin of bonded fibers on the outer surface of the roving.

The tow or roving may be produced by extruding the resin through a die having the die openings arranged in a circle using a melt blown roving technique. Gas streams, preferably air, are supplied by gas plenums in the form of slots concentrically inside and outside of the circle of die openings to attenuate the extruded resin into fine fibers. The circle of die openings are arranged in the die so as to extrude and direct the resin as a cone of fibers in space extending from the die openings, the cone of fibers being largest at the die and narrowing in an imaginary focal point in front of the die. The shape of the cone of fibers in space may be modified by controlling the relative velocities of the gas streams from the plenums inside and outside the circle of die openings to change the distance of the imaginary focal point of the cone of fibers in front of the die.

The conical profile of the fibers coming from the die openings may be further controlled by means of an auxiliary gas stream supplied through a gas plenum in the form of a jet in the center of the circle of die openings. The auxiliary gas stream assists in cooling the fibers prior to collection and also modifies the laydown of the fibers. Thus, the auxiliary gas stream may be used to change the conical shape of the fibers as they are attenuated from the die so that the profile of the fibers in space become more cylindrical at the laydown zone. By thus controlling the auxiliary gas stream, the temperature history of the extruded resin may be changed as well as the laydown pattern of the individual fibers.

The fibers may be collected as a tow in a number of distinct ways. The fibers may be collected either by moving the tow of fibers away from the die or through the center of the circle of die openings. The direction of removal of the tow of fibers formed are distinguished by defining forward takeoff as collecting and moving the tow in a direction away from the die and reverse takeoff as collecting and moving the tow of fibers back through the center of the circle of die openings. The direction of collecting and moving the tow results in the production of distinctly different products. For example, in the reverse takeoff a smooth skin of bonded fibers may be produced on the outside of the tow, while on the other hand, forward takeoff produces a softer outer layer of individual fibers and aggregates of fibers on the tow.

A fixed or rotating collecting means may be used in the laydown zone to collect the fine fibers in a desired form. The preferred collecting means is a stabilizer rod. The stabilizer rod is preferably rotated to produce a uniform tow. The rotation of the stabilizer rod produces a permanent twist in the product and eliminates the opening or soft center of the tow due to being removed from the stabilizer rod. However, if a hollow tow is desired, a large stationary or rotating rod may be used.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of the overall melt blown roving process with reverse takeoff;
FIG. 2 is a schematic view of the melt blown roving process with forward takeoff);
FIG. 3 is a pictorial representation of fiber laydown with reverse takeoff;
FIG. 4 is a pictorial representation of fiber laydown with forward takeoff; and
FIG. 5 is a schematic view of the melt blown roving process with a plurality of dies.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1 which sets forth one embodiment of the overall melt blown roving process, a thermoplastic such as polypropylene is introduced into the feed hopper 1 of an extruder 2. The thermoplastic is heated in the extruder 2 and is passed under shear by a screw (not shown) in the extruder 2 and driven by drive 3. The thermoplastic is extruded from a die 4 which has a plurality of die openings 5 arranged in a circle into a gas stream. The gas stream is supplied by gas plenums 6 and 7 arranged concentrically inside and outside, respectively, to the circle of die openings 5.

The thermoplastic is extruded from the die 4 as continuous fibers which are attenuated by the gas stream from plenums 6 and 7. Gas is supplied to the plenums 6 and 7 by lines 8, 9, respectively, each of which may be independently controlled as to pressure and temperature (not shown). By the control of the gas stream, the extruded fibers are attenuated from the die openings 5 in the shape of a cone, with the largest portion of the cone being at the die openings 5. The fibers are collected in a laydown zone 10 which is in proximity to the imaginary apex of the cone of attenuated fibers. The distance from the die openings 5 to the laydown zone 10 is controlled to a large extent by the relative gas velocities from plenums 6 and 7.

The attenuated fibers are collected on a collecting device 11 which may have various shapes and sizes. The collecting device 11 is preferably a stabilizer rod 12 which is held stationary or rotated. The stabilizer rod 12 may be placed through the center of a funnel 13 or 14 or in a slab to give a bearing to stabilize the rod 12 when rotated by a drive means 14. The funnel 13 also protects the drive means 14 from stray fine fibers. As the fibers collect on the stabilizer rod 12, they entangle and become self-bonded.

To modify the configuration of the fibers as they are collected in the laydown zone 10 on the stabilizer rod 12, an auxiliary gas stream may be supplied from a gas plenum 15 formed by a double-wall pipe 16. The double-wall pipe 16 is positioned along the axis defined by the center axis of the die 4 and the center of the circle of die openings 5. The gas stream from gas plenum 15 is directed at the collecting device 11 or stabilizer rod 12 and the air stream modifies the laydown of the fibers in laydown zone 10 so that they take a more cylindrical shape. Gas, preferably air, is supplied to the double-wall pipe 16 by line 17 which may be controlled as to pressure and temperature. The auxiliary gas stream may be used to modify the time-temperature history of the fibers as well as the configuration and entanglement of the fibers. The gas supplied through gas plenum 15 may be cooler or hotter than the air supplied through plenums 6 and 7.

To begin the melt blown roving operation, a starter rod 18 is extended into the laydown zone 10 along the stabilizer rod 12 to draw the fibers as a continuous tow from the stabilizer rod 12 either in a forward takeoff or in a reverse takeoff, the
reverse takeoff illustrated in FIG. 1. As shown in FIG. 1, the starter rod 18 is drawn through the center of the double-wall pipe 16 where the tow is attached to a windup reel (not shown).

The melt blown roving operation of the present invention allows numerous products to be produced by varying the conditions in the laydown zone 10. The fibers are extruded and attenuated from the die openings 5 initially in the form of a cone A. As the fibers converge, the individual fibers come in contact with one another and with the roving previously formed. Being hot the fibers can stick or self-bond and begin to entangle. The fibers, however, continue to attenuate and stick together and to the roving further from the die openings 5 in the laydown zone 10 until a mass of entangled and self-bonded fibers is formed. The laydown zone 10 extends from the point where initial contact of fibers occur to the furthest point away from the die openings 5 where the fibers collect in the fiber mass as a tow. The laydown zone 10 may be several inches to a foot or so from the die openings 5. The laydown zone 10 may be modified in independently varying the angle at which the extruded thermoplastic comes from the die in relation to the axis of the die, the use of the auxiliary gas stream from plenum 15 and the direction of takeoff. The use of the auxiliary gas stream from plenum 15 in most instances produces a more uniform laydown of the fibers and accordingly a more uniform tow of fibers is produced. When the tow 19 is removed from the laydown zone 10 by a reverse takeoff as illustrated in FIG. 1, the tow may have a bonded and smooth outer surface, whereas when the tow is removed from the laydown zone 10 in a forward takeoff, the outer surface appears more fluffy. A tow may be produced which is less dense and has less self-bonding by having the laydown zone 10 further away from the die openings 5.

Referring to FIG. 2, the melt blown roving technique of the present invention is illustrated with the forward takeoff. The thermoplastic resin is introduced into the feed hopper 20 of an extruder 21. The thermoplastic is heated, placed under shear by a screw in the extruder 21 driven by drive 22 and extruded from a die into a gas stream. The die has a plurality of die openings 24 arranged in a circle. The gas stream is supplied by gas plenums 25 and 26 arranged concentricly inside and outside, respectively, each of which may be independently controlled as to pressure and temperature. The extruded fibers are attenuated from the die openings 24 by the gas stream and collected in a laydown zone 29.

The collecting device 30 preferred in the forward takeoff embodiment is a stabilizer rod 31 which is rotated by drive 32. The stabilizer 31 is inserted through the center of a double-wall pipe 33 which supplies an auxiliary airstream from the gas plenum 34 which is defined by the double-wall pipe 33. To begin the operation, a starter rod 35 is placed in the laydown zone 29 and is drawn away from the die to form a roving 36. The roving 36 is wrapped around a windup reel 37 which is rotated by a motor 38.

In FIGS. 3 and 4 the looping of a single fiber is illustrated with both reverse takeoff and forward takeoff to illustrate the overall nature of the rovings produced by the melt blown roving technique. Of course, as a plurality of fibers are involved there is entanglement and some bonding between fibers so that the continuous looping from centerline of the roving to the outside surface is not always complete. When the roving made by the melt blown roving technique is pulled apart, however, the roving breaks substantially along the lines set forth as a loop to give a cone and conical socket break.

In a specific application, the melt blown polypropylene roving makes a good filter for cigarettes. One of the requirements for a commercial cigarette filter material is that it be supplied as a continuous tow that can be readily converted to the cigarette filter or as a firm, rodlike product. Thus, for a cigarette filter the circumference of the tow may be within a range of 24 to 28 mm. The bulk density of the polypropylene tow of the present invention may vary, however, is suitable as a cigarette filter between the range of 0.05 and 0.20 g/cc and preferably between 0.09 and 0.16 g/cc.

In FIG. 5 the melt blown roving technique is illustrated with a plurality of dies. By using two or more dies, towels may be produced having distinct and unusual properties. The thermoplastic resin such as polypropylene may be introduced into hoppers 40, 50 and 70 of extruders 41, 51, and 61 respectively. The resin is extruded out of the dies 42, 52, and 62. As illustrated, the first die 42 utilizes forward takeoff with a stabilizer rod 43 rotated by motor 44. The tow 45 is formed and is passed through the double-wall pipe 53 positioned along the axis of die 52. Additional fibers are bonded to the outside of the tow 45 to produce a larger tow 54 which may pass through a gauge 55. Die 52 is also operated with forward takeoff. The tow 54 is then passed through the double-wall pipe 63 positioned along the axis of die 62. The operation of die 62 is with reverse takeoff such that a smooth, bonded skin of fibers is produced on the outer surface of the tow 64. The tow 64 may be wound on a reel (not shown). While the three dies 42, 52, and 62 have been illustrated as two forward takeoff operations followed by a reverse takeoff, it is understood that when more than one die is used the possible combinations increase with the number of dies used.

The present invention will be further described by the following examples which illustrate the present invention but are not to be considered as limitations to the invention.

Using a die having 240 die openings on a circle having a diameter of 4 inches, polypropylene (30 melt flow rate) was melt blown in a device similar to that illustrated in FIG. 1 using reverse takeoff. The roving produced was cut and tested as cigarette filters. The cut filter products were compared to a commercial filter made of cellulose acetate. The specific conditions used in making the roving and the specific roving products made are set forth in table 1 hereinafter:

<table>
<thead>
<tr>
<th>Example</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conditions</strong>:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Commercial filter</td>
</tr>
<tr>
<td>Polymer rate, g/min.</td>
<td>11.4</td>
<td>17.2</td>
<td>20.0</td>
<td>11.3</td>
<td>12.9</td>
</tr>
<tr>
<td>Main air/polymer rate</td>
<td>1,410</td>
<td>1,067</td>
<td>1,313</td>
<td>1,409</td>
<td>1,355</td>
</tr>
<tr>
<td>Main air/polymer rate</td>
<td>56.5</td>
<td>27.0</td>
<td>29.78</td>
<td>56.5</td>
<td>56.5</td>
</tr>
<tr>
<td>Aux. air rate</td>
<td>0.033</td>
<td>0.793</td>
<td>1.314</td>
<td>1.279</td>
<td>91.3</td>
</tr>
<tr>
<td><em>Temp. die</em></td>
<td>686</td>
<td>680</td>
<td>698</td>
<td>576</td>
<td>647</td>
</tr>
<tr>
<td><em>Temp. air</em></td>
<td>63</td>
<td>673</td>
<td>673</td>
<td>650</td>
<td>673</td>
</tr>
<tr>
<td>Takeoff, ft/min.</td>
<td>6.53</td>
<td>10.2</td>
<td>10.3</td>
<td>5.60</td>
<td>6.85</td>
</tr>
<tr>
<td>Two rate, turns/min.</td>
<td>0.334</td>
<td>3.35</td>
<td>3.35</td>
<td>0.334</td>
<td>4.41</td>
</tr>
<tr>
<td>Blade* distance, inches</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Product total denier</td>
<td>50,100</td>
<td>50,600</td>
<td>65,000</td>
<td>59,500</td>
<td>81,700</td>
</tr>
<tr>
<td>Percent tar removed</td>
<td>28.2</td>
<td>30.0</td>
<td>26.2</td>
<td>138.4</td>
<td>47.4</td>
</tr>
</tbody>
</table>

Comparing examples 1 and 2, the higher pressure drop through the filter or roving product and the percentage of tar removal illustrates the effect of the size of the fibers in the roving. The higher air rate and lower polymer rate of example 1 produces smaller fibers and consequently higher denier and higher percentage of tar removal. In both examples 1 and 2, the overall denier of the filter product was approximately 50,000. Examples 3 and 4 illustrate the effect of fiber size in a filter product at a higher denier of approximately 60,000 with the smaller fibers being produced in example 4.
Example 5 illustrates an optimum set of conditions for obtaining a cigarette filter material wherein a lower ΔP and higher tar removal is obtained as compared to a commercial filter made of cellulose acetate.

The characteristics of the roving may be changed by controlling the rotation of the stabilizer rod in the melt-blowing process. The rotation of the stabilizer rod produces in the roving a helical turn which can be expressed in turns per inch. A more uniform and compacted roving is produced when the roving has between 0.02 and 0.8 turns per inch. When a roving is produced without any twisting or with essentially no turns per inch, the roving structure is loose and often nonuniform. A roving structure which is firm and uniform is produced at approximately 0.5 turns per inch. When the number of turns per inch approaches 1 the roving structure becomes very firm and may be too dense for use as a cigarette filter material. Further, at a level of turns per inch approaching 1 or more, there is a tendency to produce a very tight center core with a loose, untwisted outer surface. Thus, the uniformity of the twisting in the roving may be completely lost at high rotation of the stabilizer rod. It is understood that while this is highly undesirable in producing a roving for a cigarette filter, this effect may be desired in a filter material for some other use. In summary, the twist which is made a part of the roving is related to the cross-sectional uniformity of the roving product.

The outer surface characteristics of the roving are subject to a wide variation and may change the specific end use of the roving produced. In producing a roving for a cigarette filter, the proper outer surface characteristics are a pliable, bonded web surface to produce a small, firm filter. A roving having the pliable, bonded web surface may be cut to a proper filter length without changing the roving characteristics. A roving having an outer surface which is soft and unbonded appears fuzzy and lacks the necessary firmness for a cigarette filter. Further, upon cutting a soft or unbonded roving, the ends of such 158 material become frayed. If the outer surface of the roving has fused fiber agglomerates producing a harsh skin, the resulting filter product is rough, nonuniform and too firm, and cracking results when the filter material is cut. The characteristics of the outer surface on the roving are generally controlled by the distance of the laydown zone from the circle of die openings or in other words by the focusing of the extruded fibers by control of the air to a point of contact of the fibers on the roving. If the extruded fibers are collected in a laydown zone very close to the die openings, the outer surface of the roving may have a fused-fiber skin. On the other hand, if the fibers are collected in a laydown zone at a great distance from the die openings, the outer surface of the roving may be fuzzy and uneven because the fibers are unbonded. In the examples set forth in Table I, a smooth, uniform outer surface was produced using the reverse takeoff.

To further characterize the roving produced according to the present invention, reference is made again to FIGS. 3 and 4 which pictorially represent the laydown of a single fiber with reverse and forward takeoff, respectively. This pictorial representation of a single fiber illustrates a general characteristic of the roving even though it is understood that this representation is oversimplified. With the multiplicity of fibers extruded out of the die in the melt blown process, there is considerable entanglement of the fibers and self-bonding occurring throughout the roving. A generalized characteristic of the roving of the present invention, however, is illustrated in FIGS. 3 and 4 which is a looping of the fibers in the form of repeating loops which may be less than an inch to 20 inches long and looping from a point on the axis or from a small radius therefrom to a larger radius or to the outer surface of the roving. As is illustrated in FIGS. 3 and 4, the point of contact of the continuous fiber as the fiber becomes a part of the overall roving structure is at the larger radius or outer surface with reverse takeoff (FIG. 3) while the point of contact is at the axis or smaller radius with forward takeoff (FIG. 4). In each instance, however, the roving produced with reverse or forward takeoff when pulled apart by tension along its axis breaks generally along the lines of the looped fibers to produce a conical break. A further characteristic of the roving of the present invention is that the fibers making up the roving structure are of a much smaller diameter than the fibers used heretofore in making roving products. The average diameter of the fibers in the roving product produced according to the present invention may be as small as 2 to 40 microns.

In the melt-blown roving technique other thermoplastic resin may be used besides polypropylene such as the various nylons (6, 66 and 610), polystyrene, polyethylene terephthalate, polymethylmethacrylate, other polyolefins such as polyethylene, ethylene propylene copolymers. By using a partitioned die or when more than one die is used more than one kind of thermoplastic resin may be used in the melt-blown roving process of the present invention. Thus, the roving characteristics are subject to modification by using a mixture of thermoplastic resins or a laminated tow may be formed of various resins. Further, additives or binders may be incorporated into the roving by injection into one or more of the airstreams. In this manner, composite structures can be formed with special, desirable properties such as charcoal impregnated filter rods.

The nature and objects of the present invention having been completely described and illustrated and the best mode thereof set forth, what we wish to claim as new and useful and secure by Letters Patent is:

1. A roving of entangled and bonded thermoplastic fibers which comprise a plurality of essentially continuous thermoplastic fibers having an average diameter between 2 and 40 microns and said fibers being loops back and forth essentially individually and independently from adjacent fibers from points near the center of said roving to points nearer the outer surface of said roving in a fairly uniform manner.

2. A roving according to claim 1 wherein the roving is cylindrical.

3. A roving according to claim 1 wherein said fibers are self-bonded.

4. A roving according to claim 1 wherein said fibers are polypropylene.

5. A roving according to claim 4 having a bulk density within the range of between 0.05 and 0.20 g./cc.

6. A roving according to claim 4 having a bulk density within the range of between 0.09 and 0.16 g./cc.

7. A roving according to claim 4 having a smooth, firm outer surface.

8. A roving according to claim 5 wherein the roving is cylindrical.

9. A roving according to claim 8 having a circumference within the range of 24 to 28 mm.

10. A cigarette filter made from the roving of claim 4.

11. A cigarette filter made from the roving of claim 9.