Apparatus for continuously making a tube of melt blown microfibers. The tubes are useful as filter elements. Melt blown microfibers deposited longitudinally upon a circumferential surface of a mandrel are axially withdrawn from one end of the mandrel tube. Weight is controlled by the rate at which a tube is drawn from a mandrel, the rate at which microfibers are deposited on the mandrel, the rate at which the mandrel revolves, and the like.

6 Claims, 6 Drawing Figures
CONTINUOUS TUBE FORMING BY MELT BLOWING TECHNIQUE

BACKGROUND OF THE INVENTION

In the art of producing melt-blown microfibers, a plurality of spaced, aligned hot melt strands of polymeric material, or the like, are extruded simultaneously directly into the elongated zone of confluence formed by a pair of heated, pressurized, angularly colliding gas (usually air) streams, each stream typically being in a flat, sheet-like configuration and being on a different, opposed side of such strand plurality. The gas streams break up the strands into fine, filamentous structures, and move such forwardly, so that a non-woven mat thereof is continuously laid down upon a moving surface. The U.S. Naval Research Laboratory, Washington, D.C. and Esso Research and Engineering Company, Baytown, Tex., have heretofore reported research and development work on such process.

In the process, it is believed desirable to have the two flattened gas streams employed be not only as nearly identical to each other as practical (as respects such variables as gas composition, gas temperature, gas pressure, gas volume, stream angle with respect to the forward direction in which the strand plurality is being extruded, and the like), but also as uniform as possible. Thus, with respect to an individual one of such pair of streams, it is very desirable to control and maintain uniformly such variables as temperature, pressure, velocity, eddy currents, and the like. Preferably, each gas stream has a temperature about equal to that of the temperature of the strands in one presently preferred mode of practice.

In general it is believed that, in prior art processes for making melt blown microfibers, the web laid down by a combination of die head and flattened gas streams on either side thereof has been withdrawn from the moving surface upon which the web is permitted to impinge in a direction which is generally perpendicular to the direction in which the melt blown microfibers impinge on the moving surface and in a direction which is essentially the same as that in which the moving surface moves.

Unfortunately, with this arrangement only one layer or web of microfibers from each die head employed could be utilized to make a single web, so that, to make a layered structure, it is necessary to employ a plurality of spaced, parallel die heads (each equipped with its own pair of air streams) in order to provide a composite web of several different layers of separately formed microfiber webs, there being an appropriate simultaneous control of temperature conditions so that the adjacent webs bond to one another and form an integral product web.

Another disadvantage of the prior art technique for removing webs of microfibers from the formed surface has been the fact that it was not possible to form tubular webs of such microfibers.

BRIEF SUMMARY OF THE INVENTION

There has now been discovered an improved apparatus and associated process which avoids the shortcomings of the prior art and which permits one to use a single melt blown microfiber die assembly to generate continuously a web which not only may have a multiplicity of separate layers of microfibers individually laid down and fused together, but which also enables one to form tubular webs of such microfibers.

Accordingly, it is an object of this invention to provide a system for making continuously a tube of melt blown microfibers.

Another object of this invention is to provide an apparatus for making a web of melt blown microfibers which is tubular.

Another object is to provide an apparatus wherein a single microfiber die assembly can be used to generate a web composed of more than one layer of melt blown microfibers.

Another object is to provide a process for generating a tube of melt blown microfibers.

Another object is to provide a tube generating process involving continuously withdrawing axially from a revolving mandrel a layer of microfibers continuously being deposited longitudinally upon the circumferential surface thereof.

Another object is to provide in such a technique for continuously generating a tube of melt blown microfibers a system for withdrawing such a formed tube from such a mandrel which system uses a mechanism which revolves at the same rate as the mandrel.

Other and further objects, aims, purposes, advantages, utilities, and features will be apparent to those skilled in the art from a reading of the present specification and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a view in transverse section through one embodiment of apparatus of the present invention illustrating schematically the operative principles of the present invention;

FIG. 2 is a view in longitudinal section taken axially through the mandrel of the embodiment of FIG. 1 and illustrating the manner in which a tube of melt blown microfibers is generated in the practice of the present invention;

FIG. 3 is a plan view taken along the lines III—III of FIG. 2:

FIG. 4 is a plan view of one embodiment of a rotating winder assembly adapted for continuously withdrawing a tubular web produced in the practice of the present invention;

FIG. 5 is a sectional view longitudinally taken through the axis of rotation of the rotating winder shown in FIG. 4; and

FIG. 6 is a sectional view longitudinally taken through the axis of rotation of an alternative means for such a continuous tubular web withdrawal.

DETAILED DESCRIPTION

Referring to FIG. 1, there is seen an embodiment of a melt blown microfiber generating apparatus herein designated in its entirety by the numeral 10. The apparatus 10 employs a die head 11 in which a thermoplastic resin is heated and from which the molten resin is extruded. A preferred resin is a polyolefin, such as a polypropylene. When polypropylene is employed it is heated initially to temperatures in excess of about 500°F to about 900°F, and preferably in the range of from about 600°F to 650°F. The face of die body 11 is equipped with a plurality of spaced, parallel, die openings 12 through which the molten thermoplastic resin is extruded. A hot gas (usually air) exits under substan-
tially identical pressure and temperature conditions from each elongated slot or orifice 13 and 14 on either side of the die openings 12. The hot streams of gas function to attenuate the molten extruded resin strands into fibers essentially in a planar configuration which continuously moves away from the die openings 12.

Gas under pressure is conveniently supplied to each of the slots 13 and 14 from respective chambers 16 and 17, which, in the embodiment shown, are located one on either side of the die body 11. Pressurized, heated gas or air is conveniently fed into the chambers 16 and 17, respectively, from conduits 18 and 19.

Although gas temperatures and pressures can vary widely, depending upon such variables as the resin being stranded through die head 11, process conditions, product desired, and many other variables, typical gas temperatures at a slot 13 or 14 range from about 600°F to 700°F while typical gas pressures at slots 13 and 14 range from about 5 to 30 psig. The width of a gas stream issuing from a slot 13 or 14 typically ranges from about 0.010 to 0.020 inch with the length thereof being dependent upon the length of the die body 11. Gas issuing from a slot 13 and 14 is typically moving at a velocity of from about 1,200 to 1,650 feet per second. Preferably the interrelationship between each slot 13 or 14 and the die openings 12 is such that the stream angle each of slots 13 and 14 makes with respect to the die openings is identical and ranges from about 15° to 45° with respect to the vertical line midway between the slots 13 and 14 (which preferably is in the center of a plane formed by the microfibers being generated).

The angularly colliding gas streams strike the plurality of spaced, aligned, hot melt strands issuing from openings 12, on slot 13 and 14 being on each side thereof, as indicated hereinabove. Each such strand typically initially ranges in average diameter of from about 0.008 to 0.022 inches, and the spacing between strand centers typically ranges from about 0.303 to 0.050. Preferably, the so-extruded, hot melt strands move downwardly vertically, and the die openings 12 are oriented so as to lie substantially in a (hypothetical) vertical plane lying midway between the two colliding gas streams from slots 13 and 14. In one preferred mode of operation, the temperature of the gas streams is approximately equal to that of the hot melt. Those skilled in the art will appreciate that any convenient duct means may be employed to provide the desired air streams on either side of the die openings 12, and that any convenient means of construction may be used for a die body 11 to provide the desired die openings 12.

Beneath the die body 11 is positioned a mandrel 21. Mandrel 21 may be arranged so that the axis 22 thereof is parallel to the (hypothetical) line extending through the centers of the die openings 12. Microfibers from die openings 12, as attenuated by gas from slots 13 and 14 are collected on the circumferential surface portions of the mandrel 21 and form thereon a tubular web 23. As microfibers are being deposited upon the mandrel 21, the mandrel 21 is revolving. In the embodiment shown, the direction of rotation of mandrel 21 is indicated by the arrow in FIG. 1.

The mandrel 21 is supported by means permitting such to rotate coaxially on its axis such a means here being a shaft 24 at one end 26 thereof. The shaft 24 is mounted in housing 27 and the shaft 24 is journaled for rotational movements relative to housing 27 by means of a bearing assembly 34. Shaft 24 thus permits mandrel 21 to axially rotate in a cantilever manner. Shaft 24 has mounted thereon a mandrel drive gear 28 which is revolvably driven by a drive gear 29. Gear 29, in turn, is driven by a power head (not shown), such as an electric motor, or the like. The mandrel drive gear 28 in the embodiment shown drives revolvably a reach gear 31. In turn, reach gear 31 drives a timing gear 32, the timing gear 32 being mounted axially on a driven shaft 33 which rotates with gear 32.

One embodiment of means for withdrawing continuously a tubular web of melt blown microfibers from a mandrel 21 is illustrated in FIGS. 4 and 5. Here, a rotating winder assembly designated in its entirety by the numeral 36 is equipped with a spindle 37. Spindle 37 is journaled on a shaft 41 transversely between the legs portions of a U-shaped frame member 38 for axial rotational movements in bearings 39 (one bearing being in each such leg portion of frame 38). The shaft 41 is driven by a motor 42 by means of a right angle drive provided by a pair of bevel gears 43 and 44, gear 43 being secured to the drive shaft of motor 42 and bevel gear 44 being secured to an end of shaft 41. The motor 42 is driven through appropriate electrical conduits (not shown) through slip rings 46 and 47 mounted on a shaft 48. The shaft 48 is secured to the center of the base of frame 38 by a plate 49, plate 49 being secured to frame 38 by means of bolts 51 which are threadably received in the base of frame 38. The shaft 48 is mounted in a bearing assembly 52 which is adapted to support the frame 38 and various attachments thereto as herein described. The bearing assembly 52 is mounted in fixed spatial relationship to a frame 53 and frame 53 also mounts the terminal end portion of the driven shaft 33, shaft 33 being journaled in frame 53 for rotational movements by a bearing 54. Pulleys 56 and 57, on terminal ends of shafts 33 and 48, respectively, are interconnected together by means of a drive belt 58 so that pulley 56 drives pulley 57 which, in turn, rotatably drives the shaft 48, and rotates the spindle 37 end over end, the axis 62 of spindle 62 being normal to the axis 22 of mandrel 21. Thus spindle 37 is adapted to revolve end-over-end 21 at a rate approximating the rotational speed of the mandrel 21 and simultaneously to revolve about its own axis 62.

An optional but preferred feature of the rotating winder assembly 36 is a pair of rollers 58 and 59 which are so positioned as to have their nip region 61 be in spaced, parallel relationship to the axis 62 of spindle 37. The roller 58 is mounted for rotational movements between the paired forward ends 63 of the frame 38 for rotational movements relative thereto. Roller 59 is mounted for rotational movements between a pair of flattened arms 64, the forward end of each flattened arm 64 joining an opposite end of roller 59. The rear end of each arm 64 is pivotally mounted on a pin 67. Pin 67 is, in turn, mounted on a flange 66 upstanding from the base of each forward end 63. The roller 59 is yieldingly biased towards the roller 58 and the nip region 61 therebetween by means of a pair of springs 65, each spring 65 extending between an arm 64 and an adjacent forward end 63.

In operation of the rotating winder assembly 36, a tubular web member 68 formed on the mandrel 21 passes between the rollers 58 and 59 and is collapsed and flattened. The collapsed tubular web 69 is then advanced and is convolutely wound about the circumferential surfaces of the spindle 37 as the shaft 41 thereof is
driven by motor 42, the speed of motor 42 being adjusted to provide a predetermined draw rate for removing the tubular web from the mandrel 21.

Another embodiment of a means for continuously withdrawing a tubular web from a mandrel 21 is illustrated in FIG. 6. Here, a conically tapered extension 71 is axially mounted on the forward end region of a mandrel 21 so that the tapered extension 71 revolves with the mandrel 21. A pair of drive rollers 72 and 73, respectively engage the tapered extension 71 on opposite sides thereof, adjacent the forward end 74 thereof, the respective axes 76 and 77 of rollers 72 and 73 being in spaced parallel relationship to one another. One roller 73 is supported between the forward ends 63' of a frame member 38' (components similar to those of the embodiments of FIGS. 4 and 5 being similarly numbered but with the addition of prime marks thereto). The roller 72 is mounted for rotational movements between a pair of flattened arms 64', the forward end of each flattened arm 64' joining an opposite end of roller 72. The rear end of each arm 64' is pivotally mounted on a pin 67'. Pin 67' is, in turn, mounted on a flange 66 upstanding from the base of each forward end 63'. The roller 72 is yieldingly biased towards the roller 73 and the nip region 61 theretwixt by means of a pair of springs 65', each spring 65' extending between an arm 64' and an adjacent forward end 63'.

The rollers 72 and 73' are driven by a motor 42' which drives a pulley 78 by means of a bevelled gear arrangement similar to that shown for the rotating winder assembly 36. The shaft portion of each drive roller 72 and 73 is equipped with a pulley 79 and 81 respectively, and the frame 38' has mounted thereon an idler pulley 82, the idler pulley 82 being aligned with the pulleys 78, 79 and 81. A drive belt 83 interconnects pulleys 78, 79, 81 and 82. In order to drive roller 73 in a reverse direction from that of roller 72, a cross-over is provided for the belt 83 in the region between the pulleys 81 and pulley 82.

In operation, a tubular web member 68' formed on the mandrel 21 passes over the tapered extension 71 between rollers 72 and 73. The rollers 72 and 73 function to pull and move the tubular web 68' along over the tapered extension 71 thereby continuously removing a tubular web 68' from a mandrel 21.

The tubular web 68' thus removed from mandrel 21 can be cut into sections (as by means not shown) for use as tubular filter elements.

A mandrel can be coated with a slip agent, such as polytetrafluoroethylene or the like, if desired, and a mandrel cylindrical surface can be perforated and subjected to subatmospheric internal applied pressures to help microfiber web formation on such surface during tube formation.

EMBODIMENTS

The present invention is further illustrated by reference to the following Example. Those skilled in the art will appreciate that other and further embodiments are obvious and within the spirit and scope of this invention from the teachings of this present Example taken with the accompanying specification and drawings.

EXAMPLE 1

Using an apparatus configuration such as illustrated in FIGS. 1 through 3 a polypropylene web of melt blown microfibers is laid down upon a mandrel. The solid mandrel has a diameter of about 1 inch and revolves at a rate of about 200 rpm. The die from which the microfibers are generated is about 10 inches long and the die orifices are about 0.015 inches each with the spacing between orifice centers being about 0.050 inches. Strands are extruded from the die at a temperature of about 620°F and the air stream on each side of the die head is at about the same temperature at an orifice flow rate of about 130 CFM and at an angle (relative to the vertical, with respect to the microfibers at the time they impinge on the cylindrical surface of mandrel are estimated to have average diameters in the range from about 2 to 4 micro inches. The tubular web thus formed on the mandrel is continuously manually withdrawn at the rate of about 10 feet per minute. Tube lengths of about 10 inches are conveniently continuously cut from the end of the continuously generated tubular web after removal thereof from the mandrel. Cutting can be accomplished by hand using a razor knife.

I claim:

1. Apparatus for continuously making a tube of melt blown microfibers comprising
   a. a mandrel having a circumferential surface,
   b. support means supporting said mandrel and adapted to permit said mandrel to rotate on its axis,
   c. means for rotatably driving said mandrel from one end thereof,
   d. means for continuously generating a generally planar configuration of melt blown microfibers, said means being adapted to deposit longitudinally upon a prechosen length of said circumferential surface a web of melt blow microfibers, and
   e. means for continuously withdrawing generally axially from the free end of said mandrel a tubular web of microfibers formed on said circumferential surface as said mandrel so rotates and as said microfibers are so deposited, said withdrawing means revolving at substantially the same rate as said mandrel.

2. The apparatus of claim 1 wherein said microfiber planar configuration is generally aligned with the axis of said mandrel.

3. The apparatus of claim 1 wherein said withdrawing means comprises an axially rotatably driven spindle adapted to wind convolutely thereupon a circumferentially flattened form of a tube microfibers formed on said circumferential surface, the axis of said spindle being generally normal to the axis of said mandrel, said spindle being adapted to revolve end-over-end about the axis of said mandrel at a rate approximately the rotational speed of said mandrel.

4. The apparatus of claim 1 wherein said withdrawing means includes a forwardly conically tapered extension secured axially to said mandrel and a plurality of roller means positioned about said tapered extension in circumferentially spaced relationship, each said roller means being rotatably driven and adapted to remove from said mandrel a tube of microfibers formed thereon.

5. The apparatus of claim 3 further including drive means adapted to revolvably drive said spindle end-over-end at a rate substantially identical to the axial rotational speed of said mandrel.

6. The apparatus of claim 4 wherein each of said roller means is axially rotatably driven and wherein said plurality of roller means orbits about said tapered extension as said tapered extension axially revolves, the orbit rate being substantially identical to the rotational speed of said tapered extension, each of said roller means being yieldingly engaged with a different circumferential surface portion of said tapered extension.

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