# United States Patent [19]

**Blair**

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[54] **CONTINUOUS TUBE FORMING BY MELT BLOWING TECHNIQUE**


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[73] Assignee: **Beloit Corporation,** Beloit, Wis.



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[52] **U.S. Cl.** ..... **425/224;** 425/328; 425/375; 425/447; 425/457; 425/327; 264/214

[51] **Int. Cl.²** ..... **B29C 13/00;** B29C 15/00

[58] **Field of Search** ..... 425/66, 72, 80, 83, 81, 425/115, 90, 224, 101, 324, 103, 375, 325, 381, 327, 381.2, 328, 447, 457; 264/121, 119, 214, 24



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[57] **ABSTRACT**

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 Melt blown microfibers deposited longitudinally upon a circumferential surface of a mandrel are axially withdrawn from one end of the mandrel tube.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**

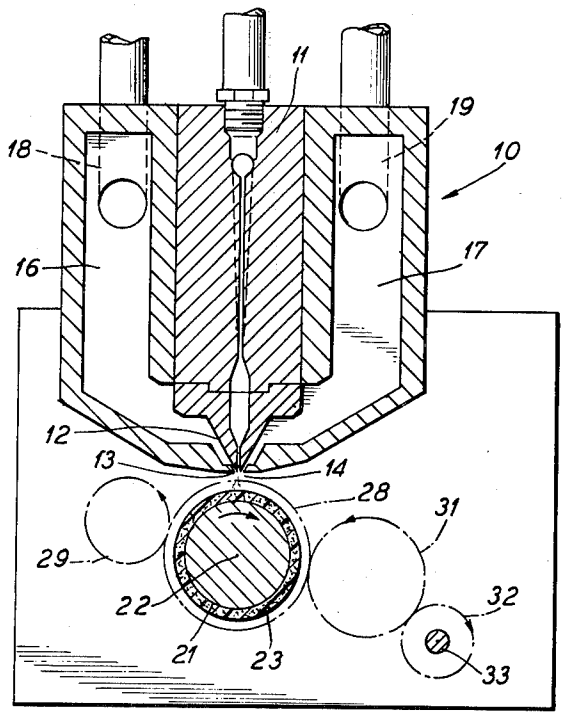


Fig 1

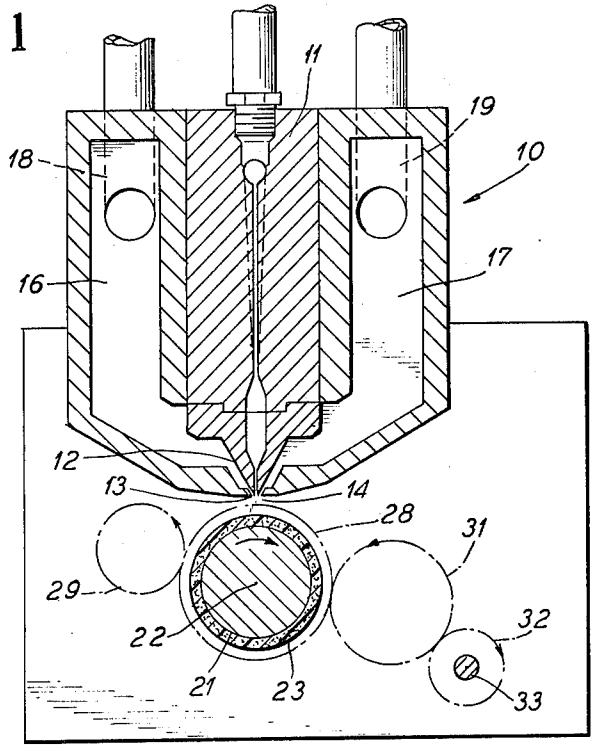



Fig. 2

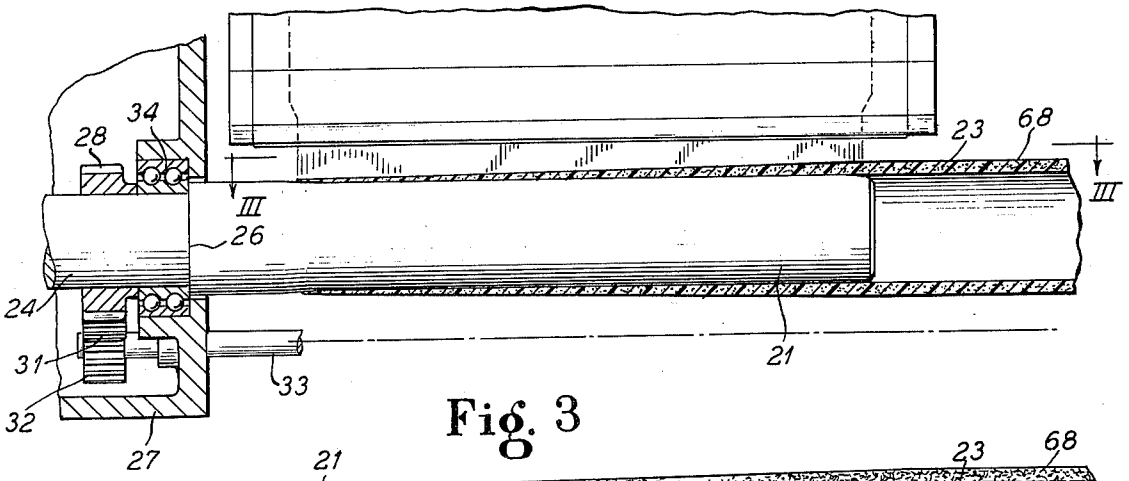



Fig. 3

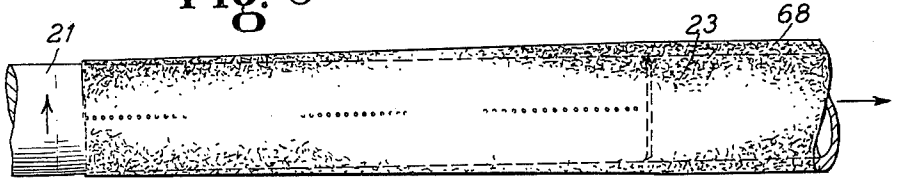


Fig. 5

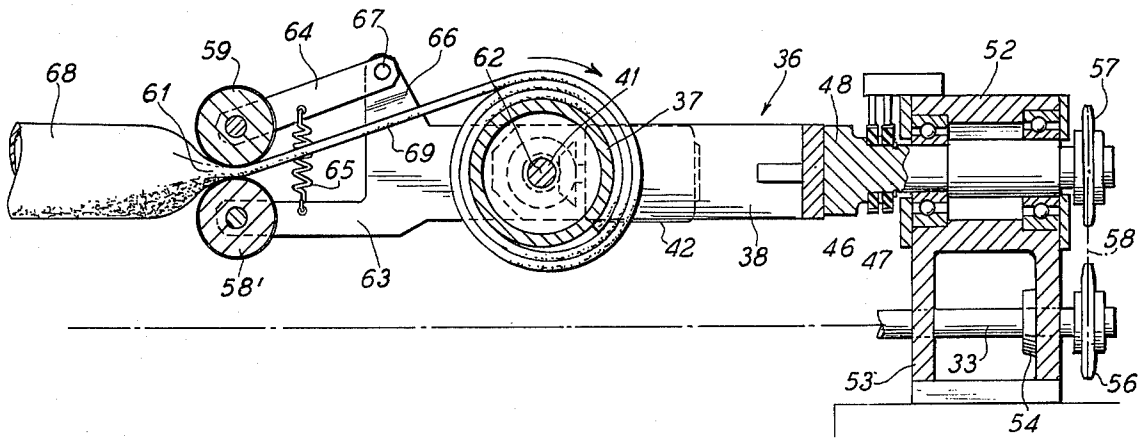



Fig. 4

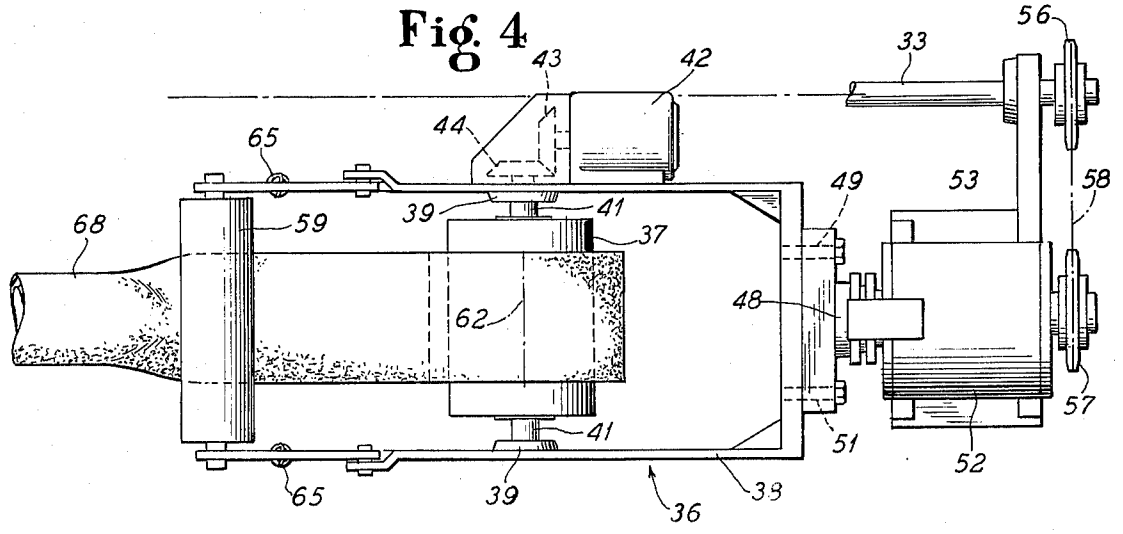
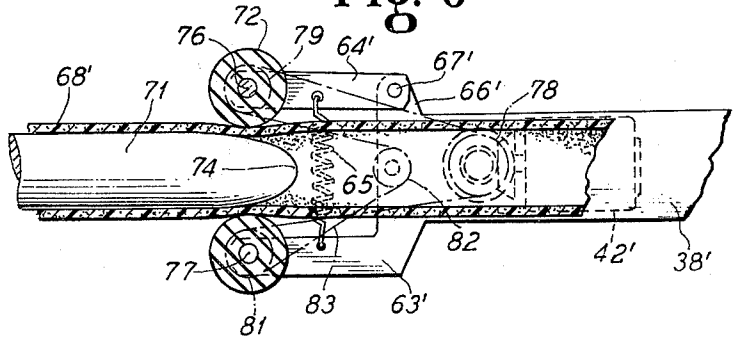



Fig. 6



# 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° 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° 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 1,630 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 0.22 inches, and the spacing between strand centers typically ranges from about 0.030 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 leg 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 **68** 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 aaxes **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** therebetween 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 pulley **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 fitter 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 has a length of about 10 inches 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) of about 30°. 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 in a collapsed, flattened form a tube of 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.

* * * * *