United States Patent

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[54] **METHOD OF BIAXIALLY ORIENTED NONWOVEN TUBLAR MATERIAL**
7 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **156/167,** 156/166, 156/180, 156/181, 156/229
[51] **Int. Cl.** **D04h 3/07**
[50] **Field of Search** 156/229, 166, 167, 180, 181, 288; 264/290

[56] **References Cited**

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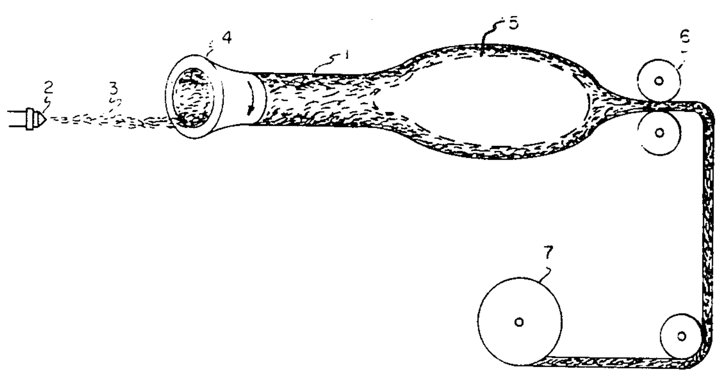
ABSTRACT: The physical properties of spray-spun nonwoven fibrous tubular structures are improved by biaxially drawing over a heated expanding mandrel. The spray-spun tube is simultaneously enlarged and elongated to produce a structure exhibiting high tensile strength.



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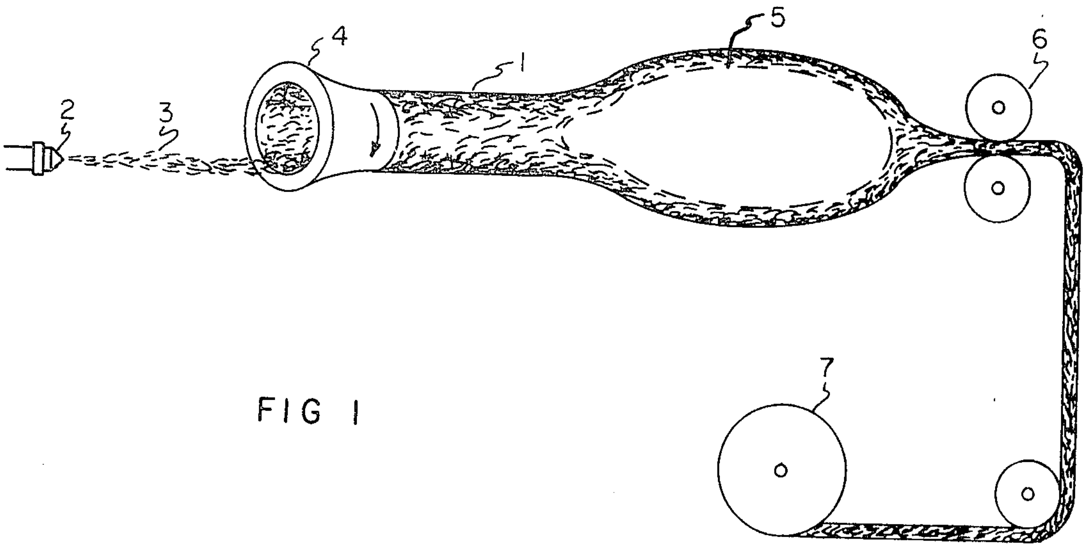

FIG 1

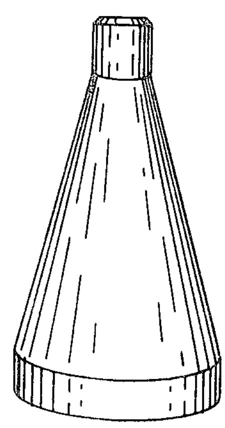

FIG 2

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METHOD OF BIAXIALLY ORIENTED NONWOVEN TUBULAR MATERIAL

BACKGROUND OF THE INVENTION

This invention relates to spray-spun fibrous tubular structures and to a method of improving the physical properties of spray-spun fibrous tubes by biaxially drawing.

Various methods have previously been advanced for producing nonwoven fibrous materials and the like directly from extruded fiber-forming materials. In general, these methods form nonwoven materials by extruding a fiber-forming polymer in liquid form through a plurality of orifices to form a like number of filaments which are either collected directly or following an intermediate drawing stage on a moving surface in the form of a mat. Examples of such methods are disclosed in U.S. Pat. Nos. 2,206,058; 2,382,290; and 2,810,426.

More recently, spray-spinning processes and apparatus have been developed which permit the formation of substantially continuous filaments at high production rate without the concurrent formation of quantities of shot and other undesirable physical forms such as very short fiber elements. The aforementioned spray-spinning processes and apparatus have been used to produce spray-spun fibrous bodies comprising randomly arranged filaments having a varying degree of crystalline orientation and a varying filament diameter along their lengths. These nonwoven spray-spun fibrous materials eliminate or substantially lessen the need for various subsequent bonding treatments by random thermal and/or adhesive bonding. The filaments are bonded to each other at crossover points and the self-bonding, in addition to some degree of filament entanglement, gives the spray-spun structure substantial coherency.

Nonwoven fibrous materials made by spray-spinning and by other similar methods should preferably have sufficient structural coherency and stability to retain their identity when handled manually or mechanically. The fibers or filaments themselves must not be made so resistant to stretching as to become brittle or susceptible to breaking when subjected to various operations to improve their properties for a particular end use. Nonwovens having insufficient tensile strength generally do not retain their dimensions on handling due to their own weight. However, the spray-spinning operation may be controlled to obtain the desired amount of tensile strength by self-bonding of the tacky fibers to each other. A bonding agent may also be utilized to increase or achieve the desired bonded strength to maintain structural coherency.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a novel method for improving the properties, particularly increasing tensile strength and drapability of spray-spun fibrous structures of substantially continuous filament material, by simultaneously biaxially orienting the material in a manner whereby increased strength and drapability are obtained.

Another object of this invention is to provide a fibrous spray-spun structure of improved drapability and tensile strength per unit area per weight.

It is still another object of this invention to provide a method for enlarging and elongating to biaxially orient a spray-spun tubular structure to increase its tensile strength, without the danger of rupturing the fibrous structure.

These and other objects will become apparent to those skilled in the art from a description of the invention. In accordance with the present invention, these and other objects of the invention are realized by spray-spinning substantially continuous filamentary material in a tubular form. The filamentary material has a varying amount of orientation and is randomly bonded to itself at crossover points between filament sections during spray-spinning so as to form varying lengths subject to drawing. During the elongation, the effective lengths are subjected to varying draw ratios between zero and the elongation ratio, thus improving the initial crystalline orientation of the filamentary material by varying amounts.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the invention may be had from a discussion of the drawings wherein:

FIG. 1 is a schematic illustration of one embodiment of the process of this invention.

FIG. 2 is an illustration of an expansion mandrel which may be utilized in a preferred embodiment of the process of this invention.

Turning to FIG. 1, the undrawn spray-spun fibrous tube 1 is produced by extruding a liquid fiber-forming material through a spinneret 2. The freshly spun filaments 3 are projected away from the spinneret in a random pattern by gas streams and a collection surface 4 is rotated and moved continuously in the path of the projected filamentary material to collect the filamentary material in a random distribution. The collected fiber forms a tube 1 that is continuously removed from the collection zone. The spray-spun fibrous tube 1 is drawn over a heated expanding element 5 such that the tube is simultaneously enlarged and elongated or biaxially drawn. The biaxially drawn material is then passed through nip rolls 6 to takeup roll 7.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

This invention can be used in connection with the production of nonwoven spray-spun fibrous structures from any of the polymers which are melt or solution spinnable. Of the various high molecular weight fiber-forming crystalline polymers that can be extruded through an orifice, the polyolefins, polyesters and polyamides are preferred. Cellulose acetate and polyacetal resins are examples of other polymers within the scope of this invention and are used with correspondingly good results. Suitable blends and copolymers of the above are also within the scope of this invention.

The spray-spinning operation may be carried out by various known processes, but it is preferably effected by the use of techniques and apparatus disclosed in the copending Patent applications of Wagner et al., Ser. No. 581,075, filed on Sept. 21, 1966, and Ser. No. 740,913, filed on June 28, 1968, now U.S. Pat. No. 3,543,332; and of Rich, Ser. No. 743,863, filed on July 10, 1968 which applications are commonly assigned to the assignee of the present application. The disclosures of these patent applications are incorporated herein by reference.

Basically, the spray spinning is effected by extruding liquid fiber-forming material, which may be either molten or plasticized and dissolved in a solvent therefor, through an orifice as a filamentary material. Preferably, attenuation of the incompletely hardened filament is effected by a plurality of high velocity gas streams issuing from gas passages spaced about the extrusion orifice and having axes that converge toward but do not intersect the extrusion orifice axis. The gas flow projects the filament away from the nozzle in an expanding conical pattern.

The filamentary material projected from the spinning zone has desirable characteristics which have been found to be particularly beneficial in the construction of nonwovens. Although the fiber is similar to conventionally spun fibers in the sense that it is in the form of a substantially continuous filamentary structure, it exhibits random lengthwise variations in diameter and degree of orientation which result from random variations in the attenuating action of the gas streams acting on the freshly spun filaments.

These variations in filament properties are usually substantial. For example, the cross section of the largest filament portion may be more than about 10 times that of the smallest filament portion, with the mean being about 3 times the cross-sectional area of the smallest filament portion. Thus, in a typical medium denier structure, the as-spun mean denier per filament is from about 12 to 18. After stretching in accordance with the present invention, the denier per filament is reduced to from about 1.5 to 15, with the average being about 4. In heavier filament structures, the denier per filament usually varies over a wider range, whereas in the lower denier ranges, e.g., 0.5 to 15, the variance is normally over a narrower range. In a nonwoven structure embodying this filamentary material, the smaller diameter segments represent a larger portion of surface area per unit volume, while the larger diameter segments are relatively stiff and resist crushing of the nonwoven.

Preferably the as-spun average denier per filament is in the range from about 1 to 30, and most preferably from 3 to 10. The preferred stretched denier per filament averages about 0.25 to 3.

As the freshly spun filament is projected away from the spinning nozzle in an expanding conical pattern by the gas streams, a collection surface, such as the surface of a tube, is rotated and moved continuously in the path of the projected filamentary material to collect the filamentary material without destroying the random distribution of the filament sections, as described in the aforementioned application of Rich. The movement of the collector surface or of the spinning orifice serves to bring new sections of the surface into the path of the filamentary material continuously so that the collected fiber forms a tube that is continuously removed from the collection zone and the fiber is uniformly deposited. The extrusion rate, the withdrawal rate and the speed of the collection surface are preferably related to each other to assure that the collected tubes will have the desired weight per unit length and uniformity for the intended use of the nonwoven.

The collection of the nonwoven spray-spun fibrous material in tubular form can be controlled so as to provide a structure of almost any weight, such as within the range of from about 0.1 to about 50 ounces or more per square yard. The particular weight of the spray-spun material produced depends upon the end use for which it is intended. For instance, when the material is to be used as a carpet backing material, the stretched product desirably has a weight of from about 4 to about 5 ounces per square yard. The spray-spun fibrous material may be originally collected in the weight range of from about 10 to 20 ounces per square yard and, on subsequent drawing, the area increase generally reduces the total weight per unit area, e.g., a reduction of from between 1 to 15 ounces per square yard. Weights of from about 0.5 to 30 ounces per square yard or more are prepared in this manner by adjusting the stretch ratio and initial fabric weight.

In controlling the weight of the nonwoven, the degree of self-bonding can also be controlled by varying the distance from the extrusion means to the collection surface so as to collect the fiber at a temperature whereby the residual heat and/or solvent retains the fiber sufficiently tacky to produce self-bonding. Of course, it will be recognized that by placing the collecting zone in a closer proximity to the extrusion orifice, an increase in bonding area occurs whereas when the collection surface is further removed, the amount of self-bonding can be reduced. In certain applications, such as for high-loft materials as contrasted with paperlike products, variations in bonding are often desired. Supplemental bonding means may also be used such as by applying a suitable bonding material to the collector along with the filamentary material or by the subsequent application of a binder. Other additives, such as colorants, fibers, selective adsorbents and the like may be similarly applied at this point.

The drawing and orientation of the spray-spun tubular material produced is effected by enlarging and elongating the tubular structure, preferably by drawing over a heated expanding mandrel. The process of this invention is effected by drawing the fibrous tubular material over a heated mandrel in the presence of heat, e.g., from about room temperature (20° C.) to just below the melting temperature of the polymer. Various drawing means can be used as well as various known heating means to produce correspondingly good results. Heating means such as radiant heating, gaseous heating, liquid heating, induction heating and the like are used. Specifically, depending upon the particular polymer used, the drawing is effected at a temperature of from about 20° to about 200° or more, and preferably in the temperature range of from about 80° to about 150°.

The principal component of the drawing operation is preferably a heated expanding mandrel-type device. The device may be a solid or perforated object, preferably metal, that is heated by electricity, radiant heat lamps, steam or other means. The mandrel maybe mounted or supported at its end and the fibrous tube drawn over the mandrel and preferably slit at a point beyond the large end of the mandrel so that it may pass the support element. The slit sheet is directed to nip rolls, in a continuous or discontinuous process. Feed and takeup may be accomplished by sets of nip rolls, by a series of driven rolls or other means which contact the mandrel. The spray-spun fiber is collected on a surface such as a rotating tube which may be separate from, or attached to, the expansion mandrel. In drawing the fiber tube over the heated expanding mandrel device, draw ratios of from about 1.1:1 to about 10:1, preferably from about 2.5:1 to 5:1 in the circumference and from about 1.1:1 to about 10:1, preferably from about 2.5:1 to 5:1 in the length are used. Thus, the total increase in the area of the nonwoven is from about 2 to 15 times or more than the original area; again, exact area increase obtainable depends upon the particular fiber characteristics enumerated above. The fibrous tube upon being drawn over the heated mandrel device may be slit and directed to nip rolls.

The present invention will be more fully described by reference to the examples which illustrate certain preferred embodiments of this invention. Unless otherwise indicated, all temperatures are in degrees centigrade and all parts and percentages are by weight.

EXAMPLE I

A polypropylene spray-spun, fibrous, nonwoven tubular material was produced in accordance with the aforementioned Rich apparatus and process, by collecting spray-spun polypropylene fiber on the exterior of a 3¼ inch diameter paper tube. The fiber tube, when cut into a 12-inch finished length, weighed about 4 ounces per square yard. The polypropylene was spun at a temperature of 350° C. on a 0.028-inch diameter nozzle of the geometric configuration described in the aforementioned Wagner et al. application. A sample of this spray-spun tube having an average denier per filament of about 4, varying from about 1.5 to 15 denier per filament, was then drawn over an expanding mandrel device that consisted essentially of a stainless steel egg-shaped bomb about 5 inches in diameter. The mandrel was supplied with superheated steam to a port in one end and allowed to discharge from a port at the other end. The bomb was heated to a surface temperature of 120° C. The fiber tube was drawn over the heated expanding portion of the bomb. This produced a 2.5:1 draw ratio in the circumference of the tube and a 1.1:1 draw ratio in the length. The appearance of the tube was similar to polypropylene sheets that had been biaxially drawn by other procedures. Good improvements in the drapability of the drawn product in all directions was obtained.

EXAMPLE II

A spray-spun polypropylene tube was again produced by collecting a fibrous tube structure on a mechanically rotating tube which passed in front of the spray-spinning extruder. Samples weighing 2 ounces and 5 ounces per square yard were prepared. An expanding mandrel, having a 3¼ inch by 11⅝ inch minimum/maximum diameter section (3.5:1 draw ratio) and constructed from a solid aluminum block was used to draw the fibrous tube. The mandrel was heated to a surface temperature of 120° C. and the drawing resulted in the expansion of the fibrous tubes in both directions.

In the same manner, tubular materials produced in accordance with the aforementioned Rich method, as well as by other variously known spray-spinning methods, can be drawn in accordance with the present invention to produce correspondingly good results. Spray-spun materials produced using various other polymeric fiber-forming materials such as polyamides, polyesters, cellulose acetate, cellulose triacetate, acrylics, conjugates thereof and the like thermoplastic polymers are used with correspondingly good results.

The fibrous structures of this invention may serve a variety of useful purposes. With suitable coating and/or lamination, they may serve in industrial applications instead of conventional woven materials, films and papers. The nonwoven structures of this invention can also serve in the preparation of felts, leatherlike materials and suedelike materials. It may also be used as interlining or interfacing materials used in imparting shape and/or stiffness to garments. In addition, the tubular nonwoven fabric may be used in the fabrication of sweaters, coats and work uniforms, or the like.

While various embodiments of the present invention have been described, the methods and elements described herein are not intended to limit the scope of this invention since changes therein are possible. It is intended that each element recited in any of the following claims is to be understood as referring to all equivalent elements for accomplishing the same results in substantially the same or equivalent manner. It is intended to cover the invention broadly in whatever form its principles may be utilized, being limited only by the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A process for biaxially orienting a spray-spun nonwoven fibrous tubular material, said spray-spun tubular material having substantially continuous filament material therein, and

having before biaxial orienting a varying amount of orientation and being randomly bonded to itself at crossover points between filament sections during spray-spinning to form varying lengths subject to drawing, said process comprising passing said tubular material over a heated expanding element and subjecting the effective lengths between crossover bond points to varying draw ratios from 1.1 to 1 to 10to 1, and thereby enlarging and elongating said spray-spun tubular structure.

2. The process of claim 1 wherein the drawing is effected at temperatures which heat the tubular material to a temperature from 20° C. to just below the melting point of the spray-spun polymer.

3. The process of claim 2 wherein the spray-spun polymer is heated to a temperature of from about 80° C. to about 200° C.

4. The process of claim 2 wherein the spray-spun polymer is heated to a temperature of from about 100° C. to about 150° C.

5. The process of claim 6 wherein the total increase in the area of the spray-spun fibrous tube is from about 2 to 15 times the original area.

6. The process of claim 1 wherein the spray-spun fibrous tubular material comprises polypropylene.

7. The process of claim 1 wherein subsequent to drawing, the spray-spun fibrous tubular material is slit and taken up on a collection means.

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,615,998 Dated October 26, 1971

Inventor(s) Charles J. Kolb, et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the cover sheet, "7 Claims" should read -- 8 Claims --.

In the Title, "TUBLAR" should read -- TUBULAR --.

Column 3, line 73, after "200°", -- C. -- should be inserted.

Column 3, line 75, after "150°", -- C. -- should be inserted.

Column 6, claim 8 should be inserted as follows:

-- 8. A process for biaxially orienting a spray-spun fibrous nonwoven tubular material comprising drawing said material over a heated expanding element, said drawing effected at temperatures which heat said tubular material to a temperature of from about 80 degrees centigrade to about 150 degrees centigrade, said tubular material being drawn at a ratio of from about 2.5:1 to 5:1 in the circumference and from about 2.5:1 to 5:1 in the length, said drawn tubular material being slit subsequent to drawing and taken up on a collection means. --.

Signed and sealed this 10th day of October 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents